

RESULTS OF WATERFLOODING IN KANSAS OIL SANDS CONTAINING VISCOUS CRUDE OILS

BY J. P. POWELL

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RESULTS OF WATERFLOODING IN KANSAS OIL SANDS CONTAINING VISCOUS CRUDE OILS^{1/}

by

J. P. Powell^{2/}

INTRODUCTION AND SUMMARY

The application of secondary producing methods for recovering additional oil from known fields has been recognized for many years as important to the economy of the nation. One of the most successful secondary methods is waterflooding, which conserves our natural resources by preventing premature abandonment of stripper leases and revitalizing previously abandoned areas.

Waterflooding as a secondary-recovery method was introduced into the Midcontinent region in 1931, and its use as such has become widespread. As with most new methods, the most favorable fields and leases received primary attention, whereas those with viscous oil or less favorable sand characteristics were bypassed. Numerous reports^{3 4 5 6/} have been published giving the results of individual waterflooding projects. In this report, attention is directed to the effect of a single factor, the viscosity of the oil produced.

Success in waterflooding has varied widely between formations, fields, and even different parts of the same reservoir. This is not surprising for there are many variables affecting the displacement mechanism and the wide

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- ^{1/} Work on manuscript completed September 1958.
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 - ^{3/} Powell, J. P., and Eakin, J. L., Water Flooding in the Oil Fields of Anderson, Franklin, Linn, and Miami Counties, Kans.: Bureau of Mines Rept. of Investigations 4991, 1953, 111 pp.
 - ^{4/} Powell, J. P., Survey of Water-Flooding Projects in Allen, Bourbon, Crawford, Labette, and Neosho Counties, Kans.: Bureau of Mines Rept. of Investigations 5317, 1957, 172 pp.; Water Flooding of Oil Sands in Butler and Greenwood Counties, Kans.: Bureau of Mines Inf. Circ. 7750, 1956, 42 pp.
 - ^{5/} Powell, John P., and Johnston, Kenneth H., A Survey of Oil Production in Oklahoma by Water Flooding. Part I. Nowata, Rogers, and Craig Counties: Bureau of Mines Rept. of Investigations 4831, 1952, 160 pp.
 - ^{6/} _____. A Survey of Oil Production in Oklahoma by Water Flooding. Part II. Counties Other Than Nowata, Rogers, and Craig: Bureau of Mines Rept. of Investigations 4832, 1951, 142 pp.

range of conditions in petroleum reservoirs. Calhoun^{7/} has classified the significant factors affecting waterflooding as follows:

1. Fluid character.
2. Rock character.
3. Rock-fluid interrelationships.
4. Past history.
5. Operational control.

It is notable that 3 of the 5 variables are largely beyond the control of the operator, and for semidepleted fields operational control is the only variable that can be readily changed. It is equally important to realize that no single factor, within wide limits, will condemn a property for waterflooding. For this reason, no rigid maximum viscosity of oil can be set as a limit of floodability.

Many investigations^{8 9 10 11 12/} have included theoretical analyses of oil displacement from porous media. Most of them recognize the particular importance of a low value of what Dykstra and Parsons^{13/} called the mobility ratio which is defined as follows:

$$r = \frac{\frac{K_d}{K_o} \frac{\mu_o}{\mu_d}}{\frac{K_o}{K_d} \frac{\mu_d}{\mu_o}},$$

where:

$\frac{K_d}{K_o}$ = the relative permeability to the displacing medium behind the bank of oil;

$\frac{K_o}{K_d}$ = the relative permeability to oil in the oil bank;

μ_d and μ_o = viscosity of displacing medium and oil, respectively.

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- ^{7/} Calhoun, John C., Jr., A Resume of Factors Governing Interpretation of Water-Flood Performance: Producers Monthly, vol. 21, No. 6, April 1957, pp. 44-48.
- ^{8/} Buckley, S. E., and Leverett, M. C., Mechanism of Fluid Displacement in Sands: Trans. AIMME, vol. 146, 1942, pp. 107-116.
- ^{9/} American Petroleum Institute, Drilling and Production Practice, 1940; Moore, T. V., A Review of the Principles of Oil-Reservoir Performance: API, New York, N. Y., 1941, pp. 97-104.
- ^{10/} American Petroleum Institute, Secondary Recovery of Oil in the United States; ch. 13, Fancher, G. H., Theoretical Considerations Involved in Secondary-Recovery Operations: API, New York, N. Y., 2d ed., 1950, pp. 175-194.
- ^{11/} Work cited in footnote 10, ch. 18, Heath, W. A., Influence of Viscosity of Crude Oil on Secondary Recovery: Pp. 228-232.
- ^{12/} Hocott, C. R., and Buckley, S. E., Measurements of Viscosities of Oils Under Reservoir Conditions: Trans. AIMME, vol. 142, 1941, pp. 131-136.
- ^{13/} Work cited in footnote 10, ch. 12, Dykstra, H., and Parsons, R. L., The Prediction of Oil Recovery by Water Flood: Pp. 160-174.

Much thought has been given to favorably changing the mobility ratio by increasing the viscosity of the displacing fluid or decreasing the viscosity of the oil. The former is impractical because of limitations as to the maximum injection pressure that may be used without damage to the reservoir, increased power cost for injecting a more viscous fluid, slower producing rate, and greater cost of most fluids of this type. The viscosity of the oil can be reduced by heat, and many field experiments^{14 15 16/} using this principle have been tried; however, they have not been successful economically.

Following a study of the feasibility of producing viscous California oils by waterflooding, Fried^{17/} reported: "The results of this investigation primarily serve to show the relative importance of oil viscosity on recovery by waterflooding."

Because it is difficult to evaluate independently the effect of oil viscosity on the results of waterflooding in the Midcontinent region, the purpose of this report is to give the results of several projects producing oil of more than average viscosity. Six projects in eastern Kansas (fig. 1), producing from four different sands, are described in detail as to history, methods of completion, operation, and results. The report also presents data on the characteristics of the injected water and produced oil.

Table 1 shows that, for these 6 projects, the absolute viscosities of the produced crude oils range from 64 to 286 centipoises (cp.) at 60° F. and from 31 to 83 cp. at 100° F. The effect of viscosity on the recovery of oil by waterflooding has been discussed by Fried.^{18/} Sage and Lacey^{19/} have shown that, although the viscosity of an oil increases with pressure, the solution of gases causes the viscosity to decrease until the saturation pressure is reached, from which point it increases. Changes with time in the viscosity of the crude oil produced during the life of a flood, shown in table 1, may be explained in part by the previous injection of air or gas into the oil sand and subsequent increases in pressure during flooding. Additional analyses of samples of oil (items 1 to 6a), produced during different periods in the life of floods, are given at the end of this report and show the changes in the characteristics of the crude oil produced during flooding.

In general, methods of waterflooding viscous oils do not differ greatly from those conventionally used. Both open and closed water-conditioning systems are employed. Completions and operational methods are similar, but input rates and pressures are carefully controlled to prevent channeling and bypassing of the injected water.

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- ^{14/} Stoval, S. L., Recovery of Oil From Depleted Sand by Means of Dry Steam: Oil Weekly, vol. 74, No. 9, Aug. 13, 1934, pp. 17-24.
- ^{15/} Lindsley, B. E., Oil Recovery by Use of Heated Gas: Oil Gas Jour., vol. 27, No. 31, Dec. 20, 1928.
- ^{16/} Kuhn, C. S., and Koch, R. L., In Situ Combustion: Oil Gas Jour., vol. 52, No. 13, Aug. 10, 1953, pp. 92-96.
- ^{17/} Fried, A. N., Effect of Oil Viscosity on the Recovery of Oil by Water-Flooding: Bureau of Mines Rept. of Investigations 5115, 1955, 34 pp.
- ^{18/} Work cited in footnote 17.
- ^{19/} Sage, B. H., and Lacey, W. N., Viscosity of Hydrocarbon Solutions: Ind. Eng. Chem., vol. 32, April 1940, pp. 587-589.

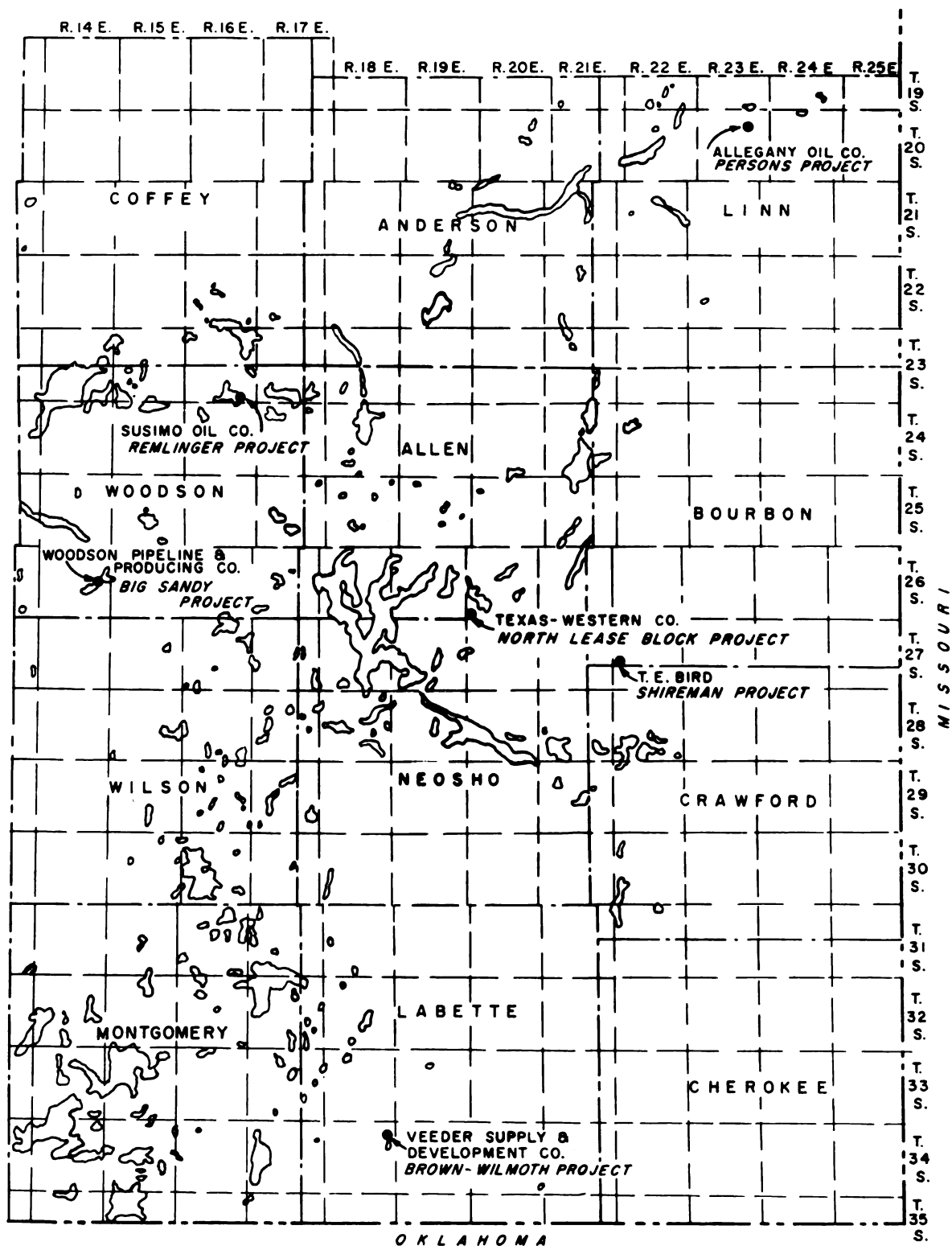


FIGURE 1. - Map Showing Locations of Waterflooding Projects in Kansas Sands Containing Viscous Crude Oils.

TABLE 1. - Viscosity and gravity of some Kansas crude-oil samples

Date sampled	Operator	Field	County	Formation	Gravity, °API	Saybolt U. Visc., sec.			Viscosity, abs.		Remarks
						60° F.	100° F.	130° F.	60° F.	100° F.	
1956 1957	Allegany Oil Co.	LaCygne- Cadmus	Linn	Peru	26.4 26.4	875 500	216 194	103 117	175 99	41 37	Expanded pilot flood.
1954 1956 1957	T. E. Bird	Hepler	Bourbon	Tucker	26.3 26.1 25.6	480 630 750	188 215 228	113 114 115	90 130 149	36 41 44	Old flood passed peak.
1956 1957	Susimo Oil Co.	Neosho Falls	Woodson	Squirrel	26.8 26.8	600 480	221 179	126 107	116 91	42 34	New flood.
1956 1957	Texas- Western Co.	Humboldt- Chanute	Allen	Bartlesville	22.0 23.1	875 1,050	312 308	168 155	179 210	61 59	Do.
1956 1957	Veeder Supply & Develop- ment Co.	Edna	Labette	do.	26.1 25.9	320 370	183 163	130 106	64 74	35 31	Old area of pilot test.
1956 1957	Woodson Pipeline & Producing Co.	Big Sandy	Woodson	do.	22.0 23.0	1,400 580	423 328	216 220	286 119	83 64	New and accidental flood.

Analyses of oil-sand cores show comparatively high porosity, permeability, and oil saturation. These factors compensate for longer recovery periods, less efficient recoveries, and lower prices of the viscous crude oils.

ACKNOWLEDGMENTS

This report was prepared by the Federal Bureau of Mines under a cooperative agreement with the Kansas State Board of Health.

The writer gratefully acknowledges the cooperation of the officials and employees of the oil companies operating the waterflooding projects described, who made this report possible by furnishing engineering and statistical data regarding their respective projects.

DISCUSSION OF INDIVIDUAL PROJECTS

Allegany Oil Co. Persons Project

Early waterflooding on the Allegany Oil Co. Persons project in sec. 11, T. 20 S., R. 23 E., Linn County, Kans., was described in a report by Powell and Eakin.^{20/} During January 1953, a pilot project (flood 1) in the "upper" Peru sand was abandoned, and flood 2 was started as a pilot test on the "lower" Peru sand. The operators, encouraged by the success of the second pilot flood, expanded it to cover 23 acres on the Persons lease. However, expansion to the south was discontinued when unfavorable sand conditions were encountered after a few wells were drilled on the Hampton lease. The project now covers approximately 23 acres on the Persons leases and about 4 acres on the Hampton leases. Like wells on the Persons lease are spaced 247 feet apart, whereas spacing on the Hampton lease was increased to 330 feet. Figure 2 is a map of the developed area and a graphical record of the waterflood oil production from the project.

The formation flooded, known locally as the Peru sand, occurs at an average depth of 220 feet and has an average thickness of 15 feet. Analyses of cores, cut before development of the flood, indicated that the formation had the following average reservoir conditions: Porosity, 20 percent; permeability to air, 106 millidarcys; oil saturation, 58 percent; and water saturation, 27 percent. The specific permeability ranged from nearly zero to 473 millidarcys, and the average effective permeability^{21/} to water was 17 millidarcys. Figure 3 shows the results of the analysis of a representative core. A sample of oil taken before water injection had an API gravity of 23.3° and a viscosity of 55 cp. at 100° F. A sample taken after the flood had been in progress more than 3 years had an API gravity of 26.4° and a viscosity of 41 cp. at 100° F. The characteristics of 2 samples, taken 1 year apart, are shown in items 1 and 1a. The lower gravity (23.3° API) and high viscosity of the sample taken before water injection probably resulted from oxidation of some components and evaporation of lighter hydrocarbons because of earlier air injection.

^{20/} Powell, J. P., and Eakin, J. L., Water Flooding in the Oil Fields of Anderson, Franklin, Linn, and Miami Counties, Kans.: Bureau of Mines Rept. of Investigations 4991, 1953, pp. 59-61.

^{21/} Effective permeability is determined by passing water through the sample without removing the fluids contained in the core as it was recovered.

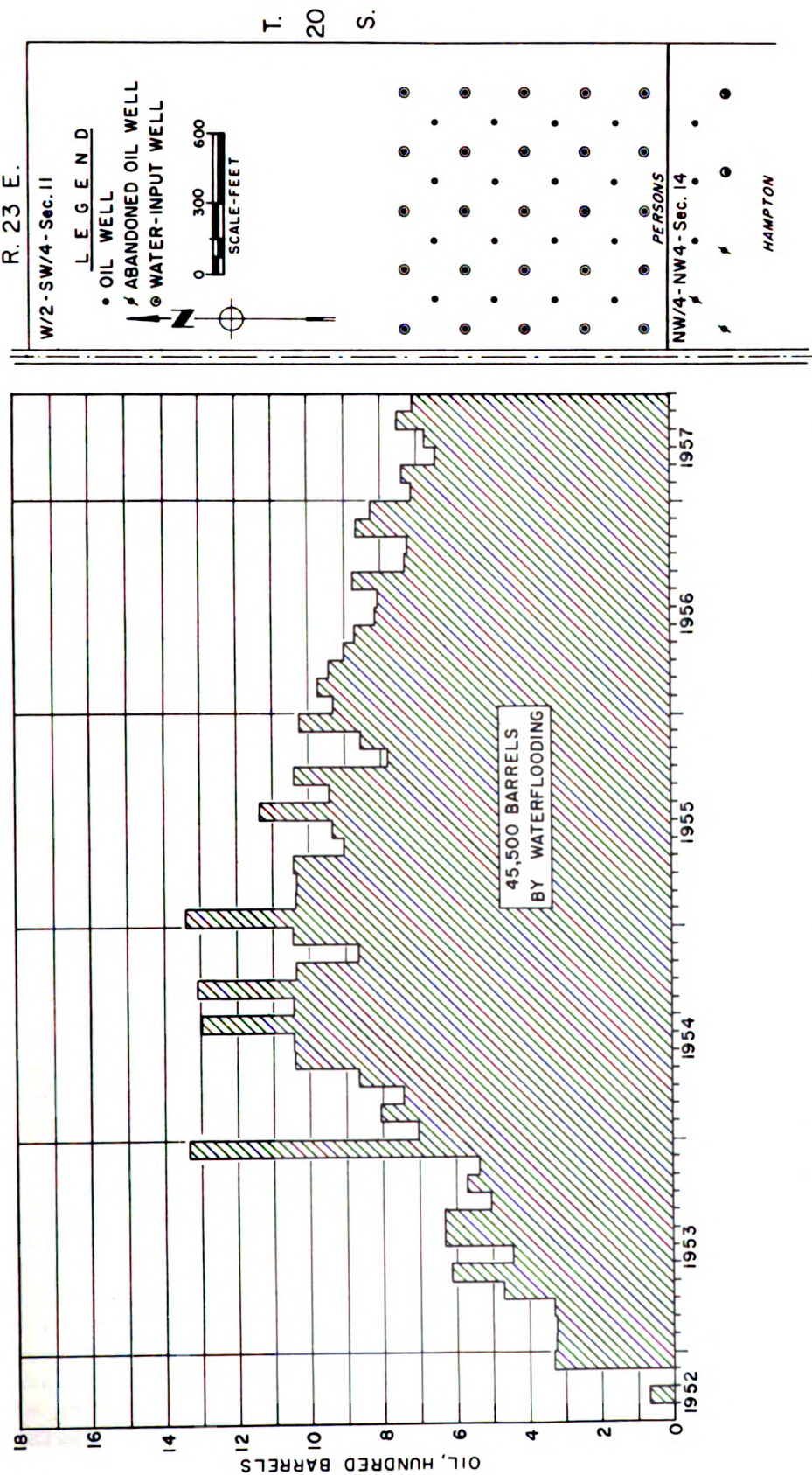


FIGURE 2. - History of Production by Waterflooding and Map of Allegany Oil Co. Persons Project, Linn County, Kans., July 1, 1957.

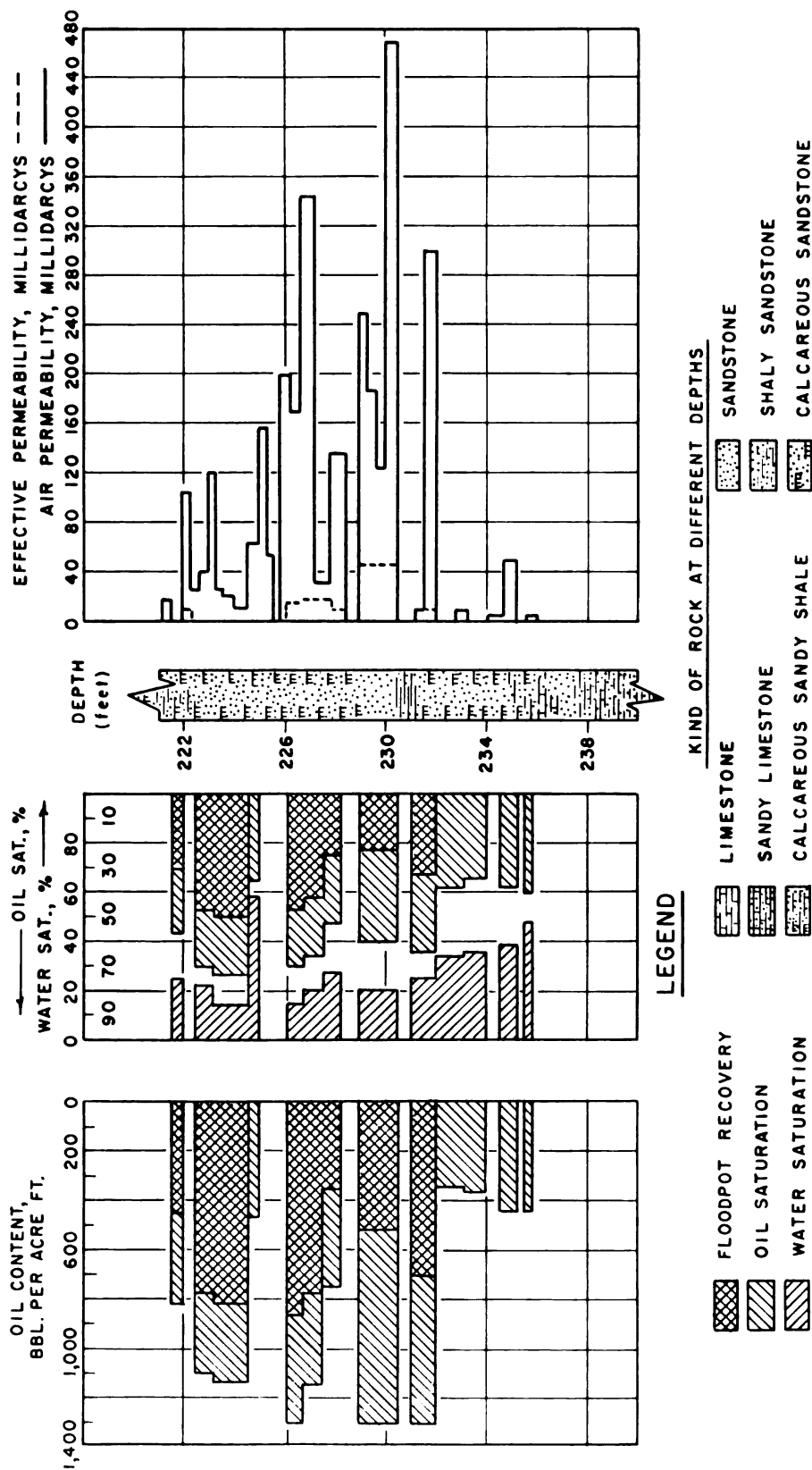


FIGURE 3. - Results of Core Analyses of Peru Sandstone, Allegheny Oil Co., Persons Project, Linn County, Kans.

History Before Flooding

The leases were drilled originally in 1919 and 1920, but few data are available concerning early primary operations. It is known that air-repressuring operations were used on the adjacent properties.

Method of Completing and Operating Wells

All abandoned wells in the flooded area were reopened and carefully plugged with cement. New water-input and oil-producing wells were drilled with cable tools.

The input wells were completed by setting 10 to 20 feet of 8-inch surface pipe and drilling to the top of the sand where 6-5/8-inch pipe was set. The formation then was drilled through, shot, and the hole was cleaned out. A burlap packer on 2-inch plain pipe was set and cemented, and the 6-5/8-inch pipe was pulled. Each well was shot with 30 to 40 quarts of nitroglycerin, care being taken to keep the shot below the top 5 feet of the formation to prevent fracturing into an overlying soft, muddy shale.

The producing wells were drilled in a similar manner, except that a 20-foot "pocket" was drilled below the oil sand, and the 6-5/8-inch pipe was reset after the shot and used as casing. The wells were then equipped for pumping with 2-inch tubing, rods, working barrels, and individual electrically operated pumping units. The wells are pumped off each morning and then shut down to allow the oil to accumulate in the shotholes and the pocket below the formation.

Source and Treatment of Water

Fresh water, from a gravel bed about 40 feet deep, is the principal source of water for flooding. A small Fairbanks-Morse pump, powered by a 2-hp. electric motor, pumps the fresh water into a 100-barrel storage tank, where it is mixed with the brine produced from the oil wells. The brine flows from the tank battery into a small pond, where it is aerated, and products of oxidation are allowed to settle out. It then flows by gravity into the storage tank. The mixed waters flow from the storage tanks by gravity through a closed filter. This conventional pressure-type filter is a 2-1/2-by 4-foot unit, with gravel and crushed anthracite as the filtering medium. From the filter the water flows into a 100-barrel clear-water storage tank that supplies a Gaso duplex injection pump. The filtered water is forced to the wells at a plant pressure of 210 p.s.i. Table 2 shows mineral analyses of samples of the filtered injection water and of the produced brine.

Special attention is given to controlling the pressure at the input wells to prevent breakthrough or channeling of the injected water. Occasionally, when a breakthrough does occur, it is noticed at the producing well by the sharp increase in the injection rate. The offending input well is shut in until the wellhead pressure has dissipated. After a few days, injection is resumed slowly and pressure built up gradually. Water was originally injected at a rate of 1 to 1-1/2 barrels of water per foot of sand; however, as the flood progressed, more attention was given to controlling wellhead

pressures. Breakthroughs have occurred at pressures as low as 100 p.s.i. Most of the channeling is the result of inherent sand characteristics. By-passing has recurred several times in the same input well.

TABLE 2. - Mineral analyses of injection waters, Allegany Oil Co.
Persons project, Linn County, Kans.

Ion or radical	Supply-well water		Produced brine	
	P.p.m.	Reacting values, percent (Palmer)	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	69	10.08	68	4.30
Magnesium (Mg)	7	1.70	8	.84
Sodium (Na)	299	38.22	813	44.86
Carbonate (CO ₃)	0	0	54	2.27
Bicarbonate (HCO ₃)	505	24.27	793	16.51
Sulfate (SO ₄)	29	1.76	24	.63
Chloride (Cl)	290	23.97	855	30.59
Total solids	1,199	100.00	2,615	100.00
Hydrogen sulfide (H ₂ S).....	None		None	
Barium (Ba)	do.		Trace	
Specific gravity	1,002		1,002	

Results of Flooding

Allegany Oil Co. has had good results on the Persons project, where the oil is moderately viscous. Through June 1957, 45,480 barrels of oil had been produced by the 19 oil wells on 27 acres. A total of 260,800 barrels of water had been injected through 27 input wells for a water injected- oil produced ratio of 5.7:1.

Rigid control of injection rates and pressures has been important in the attaining of this favorable ratio. The decline in oil-production rates was gradual in 1956 and 1957, approximately 2 percent per month. An extrapolation of the decline rate to an assumed economic limit of 70 barrels per month indicates a probable economic life of about 114 months and the recovery of more than 31,000 barrels of additional oil.

The volume of produced fluid appears to have remained fairly constant, with increases in the water-oil ratio as additional sand sections are watered out. Selective plugging of watered out or more permeable sand sections might help to recover additional oil.

Summary of Operations

Allegany Oil Co. Persons project
LaCygne-Cadmus field, Linn County, Kans.

Location - sec. 11, T. 20 S., R. 23 E.	Type of water - fresh.
Sand flooded - Peru.	Type of system - semiclosed.
Depth to top of sand - 220 feet.	First injection - September 1952.
Average sand thickness - 15 feet.	First oil increase - December 1952.
Area flooded - 27 acres.	Status - active.
Well pattern - 5-spot (247 x 247 ft.)	Gravity of oil - 26.4° API.
	Viscosity of oil - 41 cp. at 100° F.

Oil production, by years, bbl.

1941	<u>1</u> /2,201	1947	1,626	1953 <u>3</u> /	6,710
1942	1,634	1948	1,519	1954	11,799
1943	2,384	1949	1,017	1955	12,072
1944	1,971	1950	951	1956	10,264
1945	1,916	1951	816	1957	<u>4</u> /4,236
1946	1,894	1952	<u>2</u> /760		

- 1/ Waterflooding begun on flood 1 pilot operation. Primary production data not available.
- 2/ Flood 1 pilot operation abandoned; 399 barrels of oil attributed to flood 2.
- 3/ Flood 2 begun.
- 4/ First 6 months figures.

Summary of waterflood performance

Date	Acres flooded	Active water wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water injected - oil produced ratio
Dec. 31, 1952	4	8	3	100	22
Dec. 31, 1953	4	8	3	1,777	6
Dec. 31, 1954	11.5	15	8	1,644	5
Dec. 31, 1955	23	25	16	1,347	5
Dec. 31, 1956	27	27	19	1,528	5
June 30, 1957	27	27	19	1,684	6

	<u>Bbl.</u>
Water injected to July 1, 1957	260,803
Oil recovered to July 1, 1957	45,480

Monthly record of water injected and oil produced, bbl.

Month	1952		1953		1954	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January				327		702
February				324		807
March				330		743
April				470		864
May				613		1,042
June				444		1,045
July				632		1,297
August				632		1,042
September	739	0		502		1,309
October	2,244	60		569		1,037
November	2,880	0		535		866
December	2,880	339		1,332		1,045
Total	8,743	399	34,560	6,710	45,000	11,799
Month	1955		1956		1957	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January		1,339		930		712
February		1,037		973		736
March		1,034		942		645
April		1,042		900		676
May		903		870		756
June		933		816		711
July		1,135		806		
August		940		876		
September		1,039		730		
October		788		728		
November		856		869		
December		1,026		824		
Total	60,000	12,072	75,000	10,264	37,500	4,236

T. E. Bird Shireman Project

The T. E. Bird Shireman flood, in sec. 19, T. 27 S., R. 22 E., Bourbon County, Kans., causing production of oil with a viscosity of 43.5 cp. at 100° F., was started as a pilot project in October 1949. Since that time, it has been expanded from the original pilot with 6 input wells and 2 oil-producing wells to a flood with 24 active input wells and 29 oil wells, covering approximately 50 acres. The property has been producing by secondary-recovery methods continuously for the past 8 years. Figure 4 shows a map of the project and the history of oil production by waterflooding.

The formation flooded, known locally as the Tucker sand, is at an average depth of 600 feet and has an average thickness of 14 feet. Figure 5 shows a representative core analysis. Before flooding, the average reservoir conditions were as follows: Porosity, 20 percent; permeability, 113 millidarcys; oil saturation, 42 percent; and water saturation, 40 percent. The specific permeability ranged from nearly zero to 300 millidarcys, and the average effective permeability^{22/} to water was 7.2 millidarcys.

^{22/} See footnote 21, p. 6.

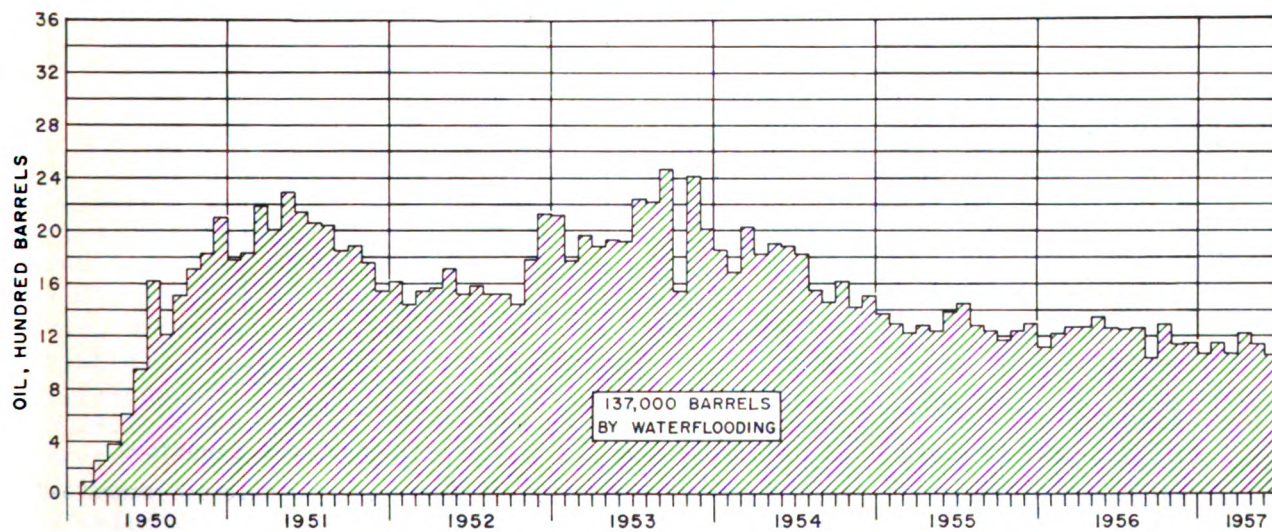
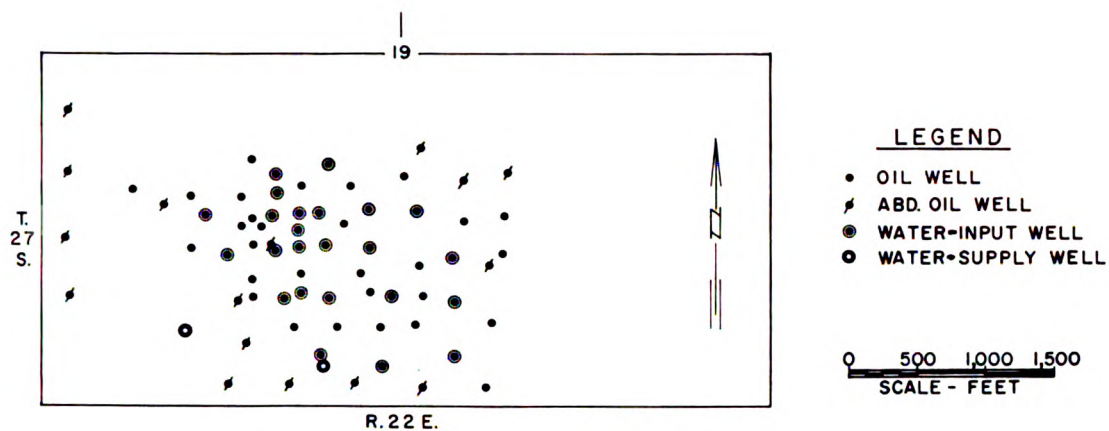


FIGURE 4. - Map and History of Production by Waterflooding of T. E. Bird Shireman Project, Bourbon County, Kans., July 1, 1957.

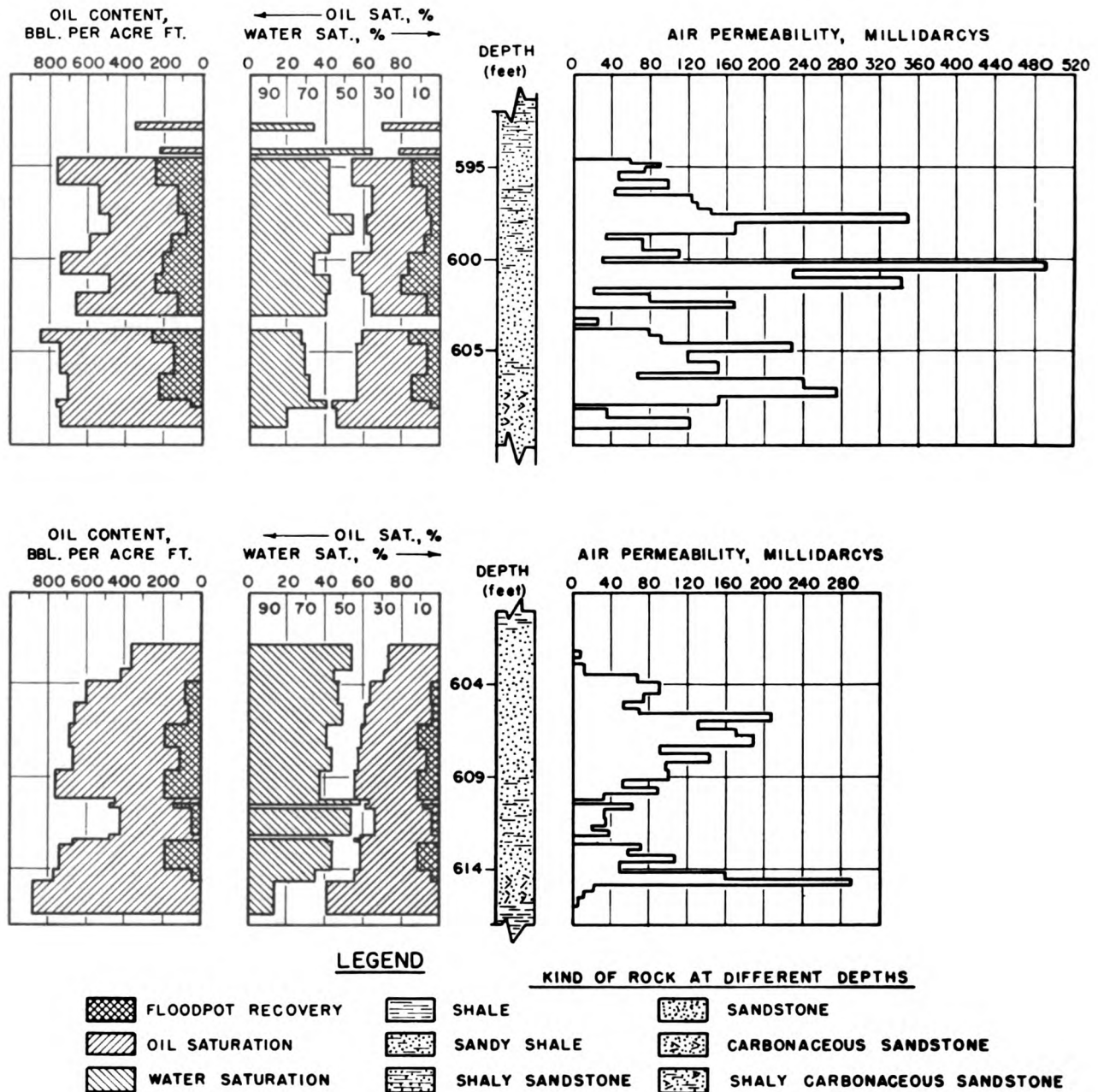


FIGURE 5. - Results of Core Analyses of Tucker Sandstone, T. E. Bird Shireman Project, Bourbon County, Kans.

The oil produced has an API gravity of 26.3° and a viscosity of 43.5 cp. at 100° F. Analyses of three samples of oil, taken during the life of the flood, are shown in items 2 - 2b. Since the first sample was taken in 1954, the gravity of the oil has decreased slightly, and that of the viscosity has increased.

History Before Flooding

The first oil well on the Shireman lease was completed in June 1917. The drilling of other wells followed, and 20 oil wells were producing by December 1918. During January 1922, approximately 65 barrels of oil was recovered daily from the lease; other primary-production records are not available. The lease was abandoned early in 1922, following an unsuccessful attempt to increase the rate of oil production by injecting air. To June 1957, 49 abandoned oil wells had been found in the producing area of the field.

Method of Completing and Operating Wells

The project was developed on a random spacing. Both water-input and oil-producing wells were completed similarly, each with 2-inch tubing set on a rag packer and cemented at the top of the oil sand. The old oil wells were reconditioned and shot, and the new wells were shot with 1 to 5 quarts of nitroglycerin per foot of oil sand.

The oil wells are equipped for pumping with insert barrels through 1-inch pipe and pumped continuously by electrically operated pumping units.

Development of the Flood

After a water-supply well and six input wells for the pilot flood were completed, a water-pumping plant was constructed, and water injection was begun in October 1949. The drilling and addition of injection wells were continued, but additional oil-producing wells were not drilled until February 1950, when two producing wells were completed. The results of the pilot operation were favorable, and the project was expanded by drilling 8 additional input and 14 oil wells in 1950. During the following year, 2 water-input and 2 oil-producing wells were drilled, extending the project to cover 35 acres. In 1952, 4 additional input and 2 producing wells were completed; this enlarged the size to cover 40 acres and increased the number of input wells and active oil wells to 20 each. Five infill oil wells were completed in 1953. No wells were drilled in 1954. In the last few years, the project has been expanded slowly. By June 1957, 24 input and 29 oil wells were active on 50 productive acres.

A triplex pump belted through a Varidrive to a 10-hp. electric motor comprises the water-pumping unit. Electric power for the injection pump and pumping units is generated at the plant site by a 25-kw. generator driven by a gas engine. A second power unit is used as a standby.

Source and Treatment of Water

An old oil well deepened to the Arbuckle formation, which in this area is at a depth of 1,008 feet, supplies water for flooding. The well is equipped with 6-1/2-inch casing cemented to the surface with 180 sacks of cement and a heavy-duty pumping jack operated by a 10-hp. electric motor. Originally, the injection water was handled in a closed system; however, that method proved unsatisfactory, and an open system was installed. The earlier methods of treating water were described in detail by Powell.^{23/} In July 1957, the brine produced from the tank battery and the water from the Arbuckle supply well flowed into a pond of about 100-barrel capacity. This shallow pond serves primarily for skimming and mixing. The mixed waters are siphoned off, flowing over a single, horizontal, tray-type aerator and into a large settling pond. This second pond, with a capacity of approximately 7,500 barrels, is divided by an earthen baffle into 2 compartments. Water flows from 1 compartment into the other through 3 buried pipes. Water flowing over the aerator at one end continues through the earthen baffle to the other end of the pond, where it is pumped into the Infilco unit. Here chemicals are added, and the water is processed. From the treating unit the water is pumped through the filters to the injection pump. A plant pressure of 540 p.s.i. is maintained, and injection pressures and water-input rates are carefully controlled at the individual wellheads. Table 3 shows the results of mineral analyses of the supply and injection waters.

Results of Flooding

Through June 1957, 136,800 barrels of oil was produced by 29 oil wells with an average of 2,733 barrels of oil per acre from the 50 developed acres. Slightly more than 1,700,000 barrels of water had been injected through 24 input wells for a water injected-oil produced ratio of 8:1. This favorable ratio has resulted from careful control of injection rates and pressures. The recovery of 2,733 barrels of oil per acre from sand 14 feet thick is equivalent to 196 barrels per acre-foot which is considered good even for less viscous oils.

During initial development of the pilot flood, injection rates of more than 2-1/2 barrels per day per foot of sand at pressures above 250 p.s.i. resulted in rapid channeling of injected water through the oil-producing formation. Lower injection pressures, with injection rates into individual wells governed by the behavior of adjacent producing wells, resulted in a steady rate of oil production with a minimum cut in water. Since 1955 injection pressures have been increased gradually, and input rates have been increased to 20,000 barrels per month.

Three input wells were fractured successfully by "Water-Frac." Several selective plugging methods have been tested. Although water-injection rates into some wells have been decreased, these treatments have not been very successful.

^{23/} Powell, J. P., Survey of Water-Flooding Projects in Allen, Bourbon, Crawford, Labette, and Neosho Counties, Kans.: Bureau of Mines Rept. of Investigations 5317, 1957, pp. 74-78.

TABLE 3. - Mineral analyses of injection waters, T. E. Bird Shireman project, Bourbon County, Kans.

Ion or radical	Supply-well water		Produced brine		Treated water	
	P.p.m.	Reacting values, percent (Palmer)	P.p.m.	Reacting values, percent (Palmer)	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	20	2.36	100	2.47	48	3.01
Magnesium (Mg)	11	2.12	74	3.00	17	1.76
Sodium (Na)	444	45.52	2,070	44.53	828	45.23
Carbonate (CO ₃)	0	0	0	0	35	1.47
Bicarbonate (HCO ₃) ...	690	26.66	885	7.17	667	13.73
Sulfate (SO ₄)	78	3.81	18	.18	86	2.25
Chloride (Cl)	294	19.53	3,060	42.65	920	32.55
Total solids	1,537	100.00	6,207	100.00	2,601	100.00
Hydrogen sulfide (H ₂ S)	Present		None		None	
Barium (Ba)	None		20 p.p.m.		Do.	
Specific gravity, 60°F.	1.002		1.005		1.003	

During the past 2 years the rate of oil production has declined only about 6 percent per year, with little change in number of active wells or area of the flood.

A conservative extrapolation of the production-decline curve indicates an ultimate recovery exceeding 200,000 barrels of oil for the property.

Summary of Operations

T. E. Bird, Shireman project Hepler field, Bourbon County, Kans.

Location - sec. 19, T. 27 S., R. 22 E.	Type of water - brine.
Sand flooded - Tucker	Type of system - open.
Depth to top of sand - 600 feet.	First injection - October 1949.
Average sand thickness - 14 feet.	First oil increase - February 1950.
Productive area - 200 acres (estimated).	Status - active.
Area flooded - 50 acres.	Gravity of oil - 26.3° API.
Well pattern - 5-spot (irregular).	Viscosity of oil - 43.5 cp. at 100° F.

Oil produced and water injected by years, bbl.

Date	Oil	Water	Date	Oil	Water
1950 ^{1/}	12,322	^{2/} 85,924	1954	20,565	119,721
1951	23,476	166,152	1955	15,500	140,000
1952	19,383	96,479	1956	14,578	240,000
1953	24,505	102,169	1957	^{3/} 6,540	120,000

^{1/} Primary production data not available.

^{2/} Includes water injected to 1949.

^{3/} First 6 months figures.

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water injected - oil produced ratio
Dec. 31, 1949	4	6	0	-	-
Dec. 31, 1950	25	14	16	493	7
Dec. 31, 1951	35	16	18	1,023	7
Dec. 31, 1952	40	20	20	1,380	6
Dec. 31, 1953	40	20	25	1,992	6
Dec. 31, 1954	40	20	25	2,506	6
Dec. 31, 1955	45	23	28	2,572	6
Dec. 31, 1956	50	24	29	2,607	7
June 30, 1957	50	24	29	2,737	8

Bbl.

Water injected to July 1, 1957	1,070,445
Oil recovered by waterflooding to July 1, 1957	136,869

Monthly record of water injected and oil produced, bbl.

Month	1950		1951		1952	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January			12,926	1,784	8,466	1,612
February	<u>1</u> /13,458	99	10,180	1,832	8,643	1,446
March	4,873	264	11,491	2,190	8,558	1,548
April	4,639	380	15,507	2,062	8,006	1,573
May	3,819	612	17,181	2,293	8,403	1,721
June	3,286	947	20,185	2,138	7,944	1,514
July	4,948	1,642		2,060	7,633	1,581
August	7,260	1,217	60,703	2,049	7,310	1,515
September	21,180	1,514		1,851	7,120	1,515
October	2,396	1,711		1,895	7,233	1,443
November	10,171	1,836	8,073	1,768	8,031	1,785
December	9,894	2,100	9,906	1,554	9,132	2,130
Total	85,924	12,322	166,152	23,476	96,479	19,383

Month	1953		1954		1955	
January	8,123	2,119	8,958	1,858	10,000	1,378
February	8,045	1,775	8,267	1,685	10,000	1,296
March	9,195	1,970	7,682	2,028	10,000	1,233
April	8,493	1,883	10,219	1,822	10,000	1,284
May	9,136	1,933	11,622	1,900	10,000	1,239
June	8,659	1,925	10,437	1,882	10,000	1,382
July	9,321	2,239	10,680	1,829	10,000	1,453
August	9,674	2,220	10,569	1,559	10,000	1,285
September	9,570	2,473	9,773	1,461	10,000	1,238
October	7,715	1,541	10,964	1,615	10,000	1,169
November	6,154	2,417	10,872	1,415	20,000	1,245
December	8,084	2,010	9,678	1,511	20,000	1,298
Total	102,169	24,505	119,721	20,565	140,000	15,500

1/ Includes water injected in 1949.

Monthly record of water injected and oil produced, bbl. (Con.)

Month	1956		1957	
	Water injected	Oil produced	Water injected	Oil produced
January		1,119		1,043
February		1,225		1,120
March		1,279		1,040
April		1,276		1,196
May		1,347		1,109
June		1,266		1,032
July		1,256		
August		1,267		
September		1,033		
October		1,271		
November		1,117		
December		1,122		
Total	240,000	14,578	120,000	6,540

1/ Includes water injected in 1949.

Susimo Oil Co. Remlinger Project

In February 1952, Susimo Oil Co. began injecting water into 11 input wells on the Remlinger project in sec. 24, T. 23 S., R. 16 E., Neosho Falls field, Woodson County, Kans. The project covers about 90 acres, with 14 input wells and 23 oil wells arranged in an irregular pattern. Figure 6 shows the oil-production history of the leases and location of the wells on the project. The serious drop in the rate of oil production in July 1951 resulted from a shutdown of operations caused by inundation of the leases by the Neosho River. During January 1952, the rate of oil production decreased because 20 oil wells were converted to water-input wells.

The formation flooded is the Squirrel sand, which is at an average depth of 950 feet and has an average thickness of 8 feet. The oil sand has an average porosity of 22 percent and an average effective permeability of 9 millidarcys. Results of analyses of cores taken before flooding indicate an average oil saturation of 45 percent and an average water saturation of 20 percent. Figure 7 shows the results of analysis of a representative core. Oil produced from the formation has an API gravity of 26.8° and a viscosity of approximately 42 cp. at 100° F. Items 3 and 3a show analyses of samples of the crude oil obtained in 1956 and 1957. Gravity of the oil produced during the life of the project remained constant; however, the viscosity showed improvement, decreasing from 41.8 to 33.7 cp. at 100° F.

History Before Flooding

Original development of these properties was begun in April 1950 and continued through March 1951. Thirty-one wells were drilled and produced by primary methods until the start of waterflooding in February 1952.

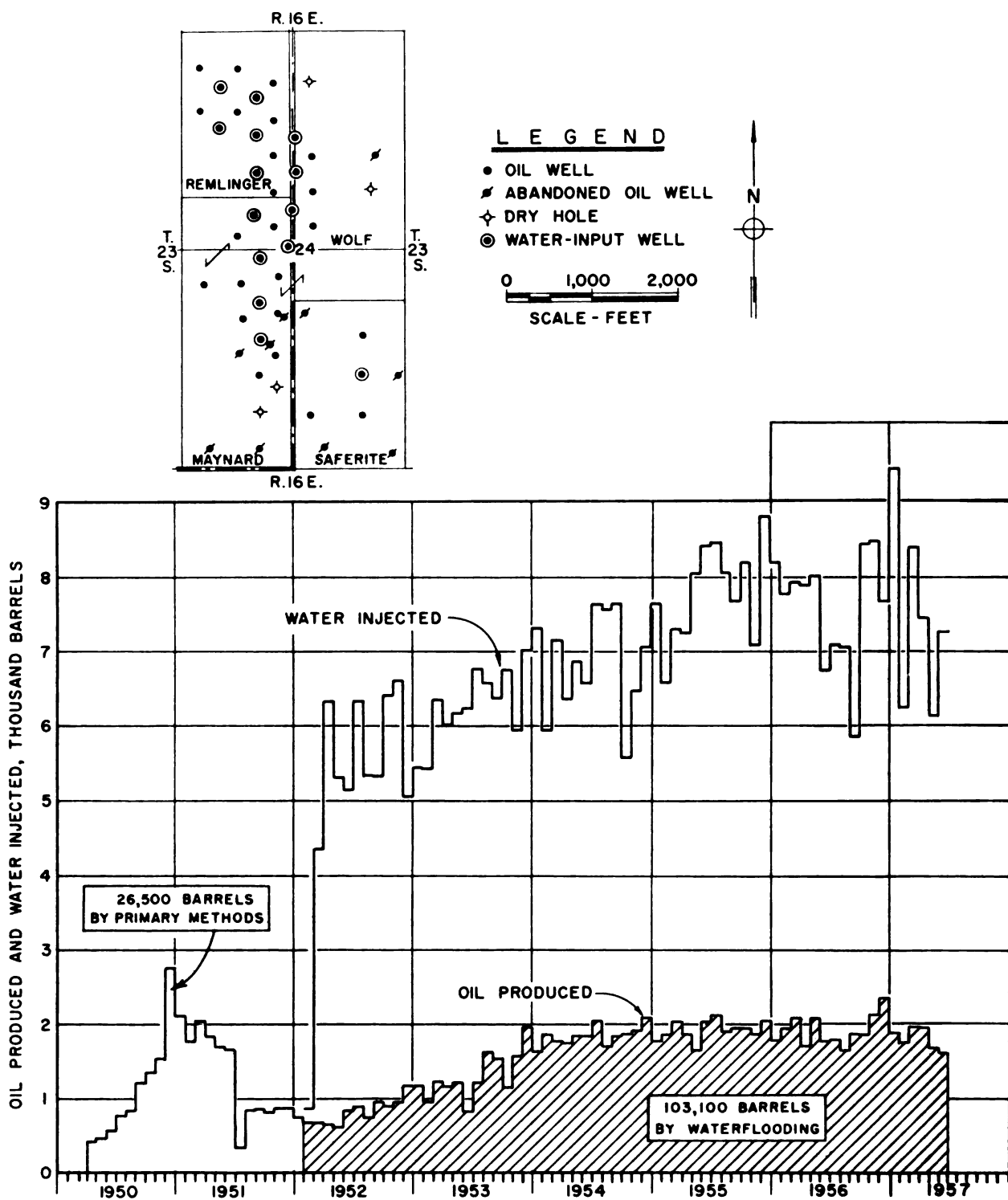


FIGURE 6. - Map and Production History of Susmio Oil Co. Remlinger Project, Neosho Falls Field, Woodson County, Kans., July 1, 1957.

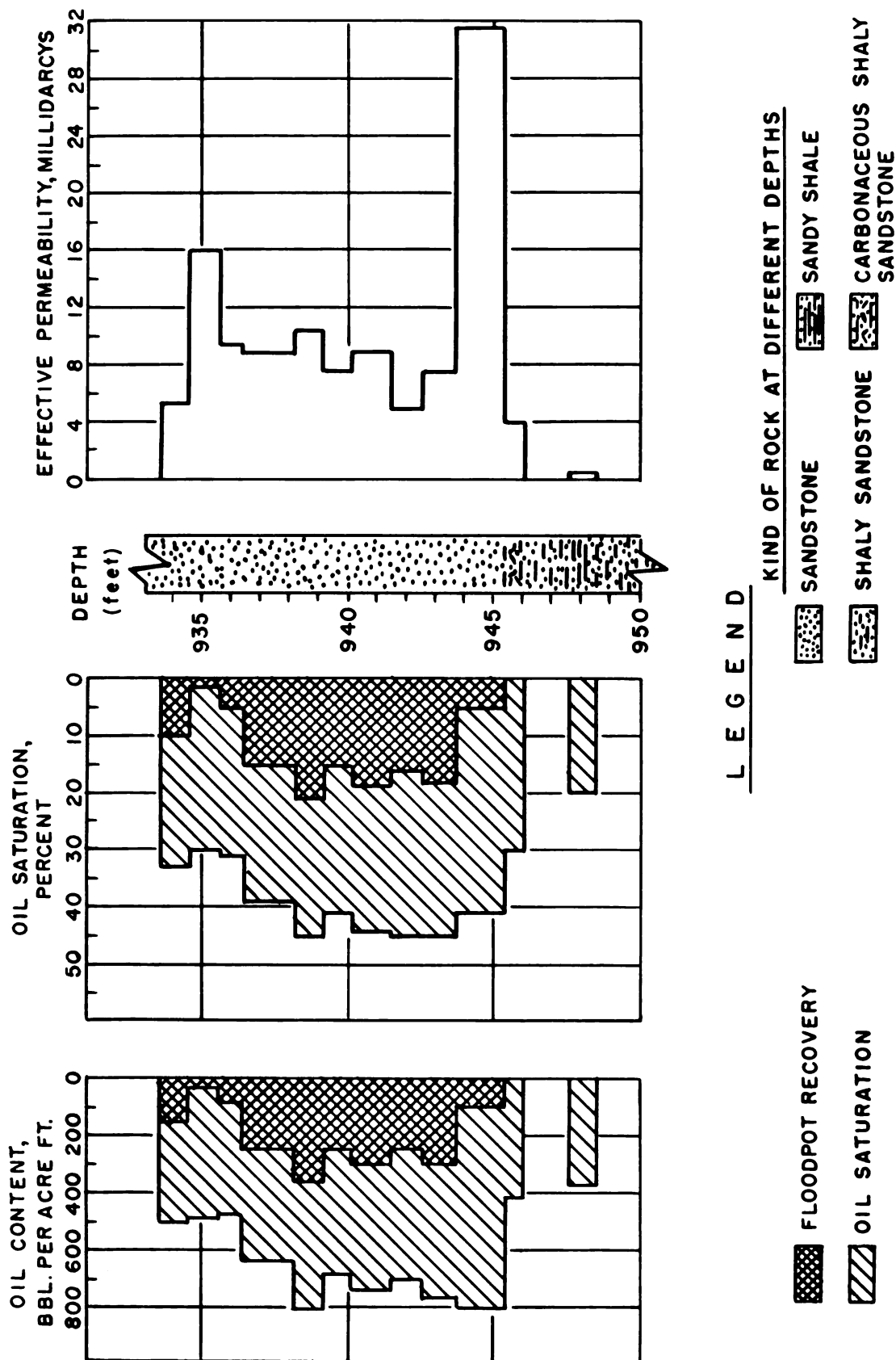


FIGURE 7. - Results of Core Analysis of Squirrel Sandstone, Susmio Oil Co.
Remlinger Project, Woodson County, Kans.

Method of Completing and Operating Wells

All wells were drilled with cable tools, and in each well approximately 40 feet of surface pipe was set through shallow gravel beds to protect fresh-water sands. A 6-1/4-inch hole was then drilled to the top of the Squirrel sand, which, in this area, is at a depth of about 950 feet. The oil sand was cored, and 5-1/2-inch pipe was set at the top of the sand. Each well was shot with 3-1/2 quarts of nitroglycerin per foot of pay sand, cleaned out, and equipped with tubing and individual, electrically operated pumping units.

At the start of waterflooding, 20 oil wells were converted to water-input wells; later 3 other wells were converted to injection wells. In converting oil-producing wells to water-input wells, casing strings were pulled, the holes were cleaned and swabbed, and rag packers on 2-inch plain tubing were set and cemented with 10 to 15 sacks of cement per well at the top of the oil sand. Meters and control valves were installed at the wellheads to control water-input rates, which were determined by the number of feet of exposed sand in each well. A maximum injection rate of 2-1/2 barrels of water per foot of sand was used. Wellhead pressures of the input wells ranged from 200 to 340 p.s.i.

Source and Treatment of Water

Two wells, completed at a depth of 250 feet in the Kansas City limestone, supply brine for flooding. These wells are cased with 6-7/8-inch pipe, equipped with 3-inch tubing and working barrels, and pumped with individual electric units. From the wells, the water is pumped into a covered 400-barrel wooden tank used as a storage tank. An oil seal on the surface of the brine in the storage tank minimizes the absorption of oxygen by the water. The brine produced with the oil is collected from the tank batteries and pumped into the storage tank where it mixes with the brine from the supply wells.

A centrifugal pump forces water from the storage tank into the intake of the injection pump. The high-pressure injection pump, a triplex pump with chrome-plated plungers and powered by a 20-hp. induction motor, forces brine into the water-distribution line at a pressure of 460 p.s.i. Table 4 shows mineral analyses of the injected and produced brines.

Results of Flooding

As a result of waterflooding, the rate of oil production increased gradually from 9,818 barrels in 1952 to 22,851 barrels in 1955. Largely because 3 more input wells were added in 1956, the rate of oil production during that year was sustained at 22,669 barrels. For the first 6 months of 1957, oil production was only 5 percent less than for the corresponding period in 1956.

Since waterflooding was begun in February 1952, the project has resulted in recovery of more than 103,000 barrels of oil, equivalent to 1,146 barrels per acre. This recovery represents about 19 percent of the oil indicated by core analyses to be in place in the sand at the start of flooding or more than half of the 275 barrels per acre-foot shown by flood-pot tests to be recoverable.

TABLE 4. - Mineral analyses of injection waters, Susimo Oil Co. Remlinger project, Neosho Falls field, Woodson County, Kans.

Ion or radical	Supply-well water		Produced brine	
	P.p.m.	Reacting values, percent (Palmer)	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	560	38.01	280	26.54
Magnesium (Mg)	79	8.83	6	93
Sodium (Na)	533	3.16	272	22.53
Carbonate (CO ₃)	0	0	0	0
Bicarbonate (HCO ₃)	165	3.69	128	3.99
Sulfate (SO ₄)	3	.08	1	.04
Chloride (Cl)	1,205	46.23	858	100.00
Total solids	2,545	100.00	1,545	100.00
Hydrogen sulfide (H ₂ S)	None detected		None detected	
Barium (Ba)	12		0	
Specific gravity	1,011		1,005	

A total of 444,000 barrels of water has been injected, giving a water injected-oil produced ratio of 4.3:1. This exceptionally good ratio has resulted from careful control of injection rates and pressures.

The volume of brine produced with the oil is increasing, indicating that some highly permeable sand sections have been watered out. Selective plugging of these sections might increase the flooding efficiency and result in additional oil recovery.

Summary of Operations

Susimo Oil Co. Remlinger project Neosho Falls field, Woodson County, Kans.

Location - sec. 24, T. 23 S., R. 16 E.	Type of water - brine.
Sand flooded - Squirrel.	Type of system - closed.
Depth to top of sand - 950 feet.	First injection - February 1952.
Average sand thickness - 8 feet.	First oil increase - June 1952.
Productive area - 106 acres.	Status - active.
Area flooded - 90 acres.	Gravity of oil - 26.8° API.
Well pattern - irregular.	Viscosity of oil - 41.8 cp. at 100° F.

Oil produced and water injected by years, bbl.

Year	Oil	Water	Year	Oil	Water
1950	9,949	-	1954	22,126	82,145
1951	15,791	-	1955	22,851	93,421
1952 ^{1/}	9,813	57,151	1956	22,669	91,086
1953	15,689	75,164	1957 ^{2/}	10,727	44,949

^{1/} Waterflooding began.

^{2/} First 6 months figures.

	<u>Bbl.</u>
Recovery by primary methods to February 1, 1952	26,490
Recovery per acre (90 acres) by primary methods to February 1, 1952	294
Water injected to July 1, 1957	443,916
Oil recovered by waterflooding to July 1, 1957	103,125
Oil recovered per acre by waterflooding to July 1, 1957	1,146

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water injected - oil produced ratio
Dec. 31, 1952	86	11	20	105	6
Dec. 31, 1953	86	11	20	288	5
Dec. 31, 1954	86	11	20	545	5
Dec. 31, 1955	86	12	20	811	4
Dec. 31, 1956	90	14	20	1,027	4
July 1, 1957	90	14	23	1,146	4

Monthly record of water injected and oil produced, bbl.

Month	1952		1953		1954	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January			5,438	1,164	7,300	1,611
February	881	684	5,417	958	5,902	1,853
March	4,444	682	6,360	1,231	7,143	1,785
April	6,320	663	6,001	1,163	6,348	1,744
May	5,290	610	6,175	1,211	6,878	1,844
June	5,116	820	6,238	822	6,594	1,835
July	6,320	890	6,781	1,210	7,683	2,019
August	5,327	752	6,583	1,616	7,568	1,694
September	5,310	960	6,381	1,515	7,629	1,811
October	6,408	891	6,745	1,164	5,581	1,858
November	6,672	949	5,935	1,667	6,475	1,901
December	5,063	1,162	7,110	1,968	7,044	2,171
Total	57,151	9,063	76,164	15,689	82,145	22,126
Month	1955		1956		1957	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January	7,627	1,779	8,175	1,789	9,453	1,874
February	6,571	1,841	7,752	1,927	6,253	1,716
March	7,298	2,005	7,905	2,093	8,406	1,952
April	7,250	1,857	7,885	1,701	7,446	1,945
May	8,039	1,631	7,999	2,080	6,116	1,650
June	8,405	2,003	6,732	1,748	7,275	1,590
July	8,458	2,105	7,093	1,765		
August	8,034	1,892	7,056	1,612		
September	7,663	1,993	5,851	1,857		
October	8,195	1,934	8,470	1,830		
November	7,078	1,852	8,491	2,013		
December	8,803	2,019	7,677	2,254		
Total	93,421	22,851	91,086	22,669	44,949	10,727

Texas-Western Co. North Lease Block Project

The Texas-Western Co. North Lease Block project in secs. 29 and 30, T. 26 S., R. 20 E., in Allen County, Kans., has been expanded from a pilot test covering 5 acres on the Campbell lease to more than 25 acres. Nine input wells have been drilled affecting 9 producing wells, and an active drilling program is in progress. Figure 8 shows a development map of the project.

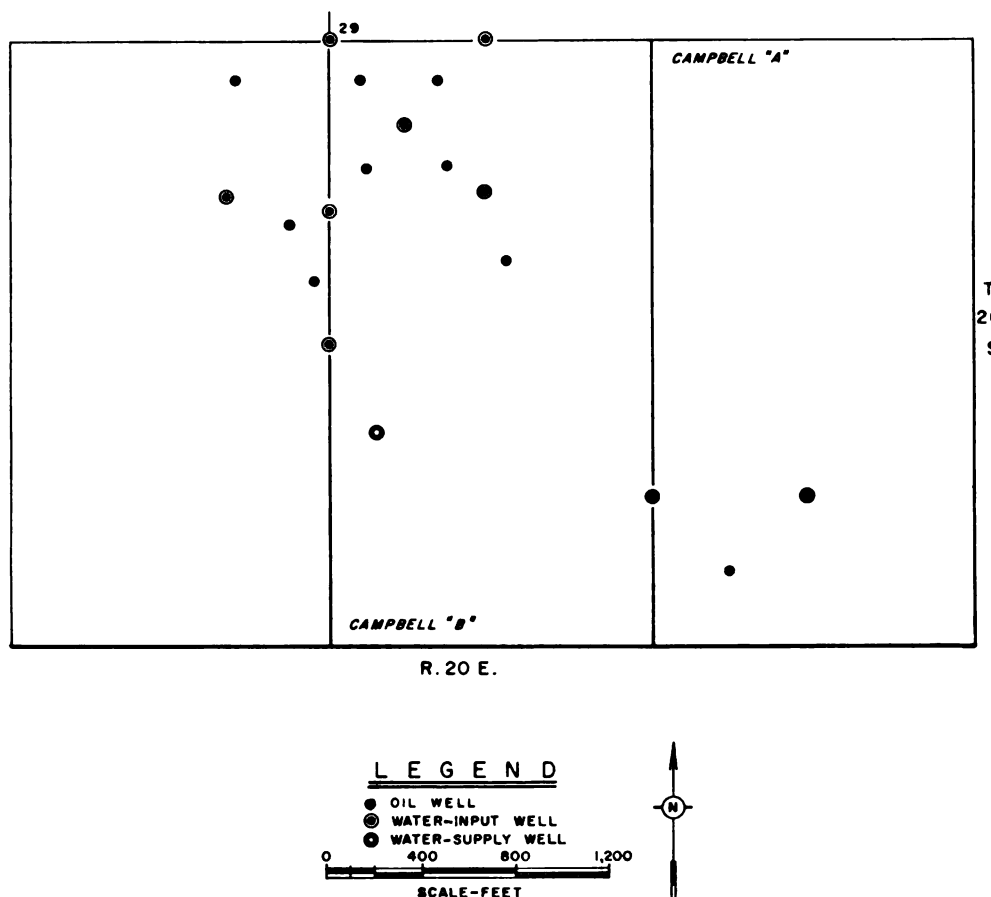


FIGURE 8. - Map of Texas-Western Co. North Lease Block Project, Allen County, Kans., Nov. 1, 1957.

The formation flooded is the Bartlesville sand, which has an average thickness of 19 feet in the area flooded and is at an average depth of 800 feet. Analyses of cores (fig. 9), taken before flooding was started, indicated the following average reservoir conditions: Porosity, 21 percent; permeability, 362 millidarcys (ranging from nearly zero to 568 millidarcys); oil saturation, 40 percent; and water saturation, 38 percent. Oil produced has an API gravity of 23° and a viscosity of 59.8 cp. at 100° F. Analyses of oil samples taken in 1956 and 1957 (items 4 and 4a) show a slight increase in API gravity and a decrease in viscosity of the oil produced since the start of water injection.

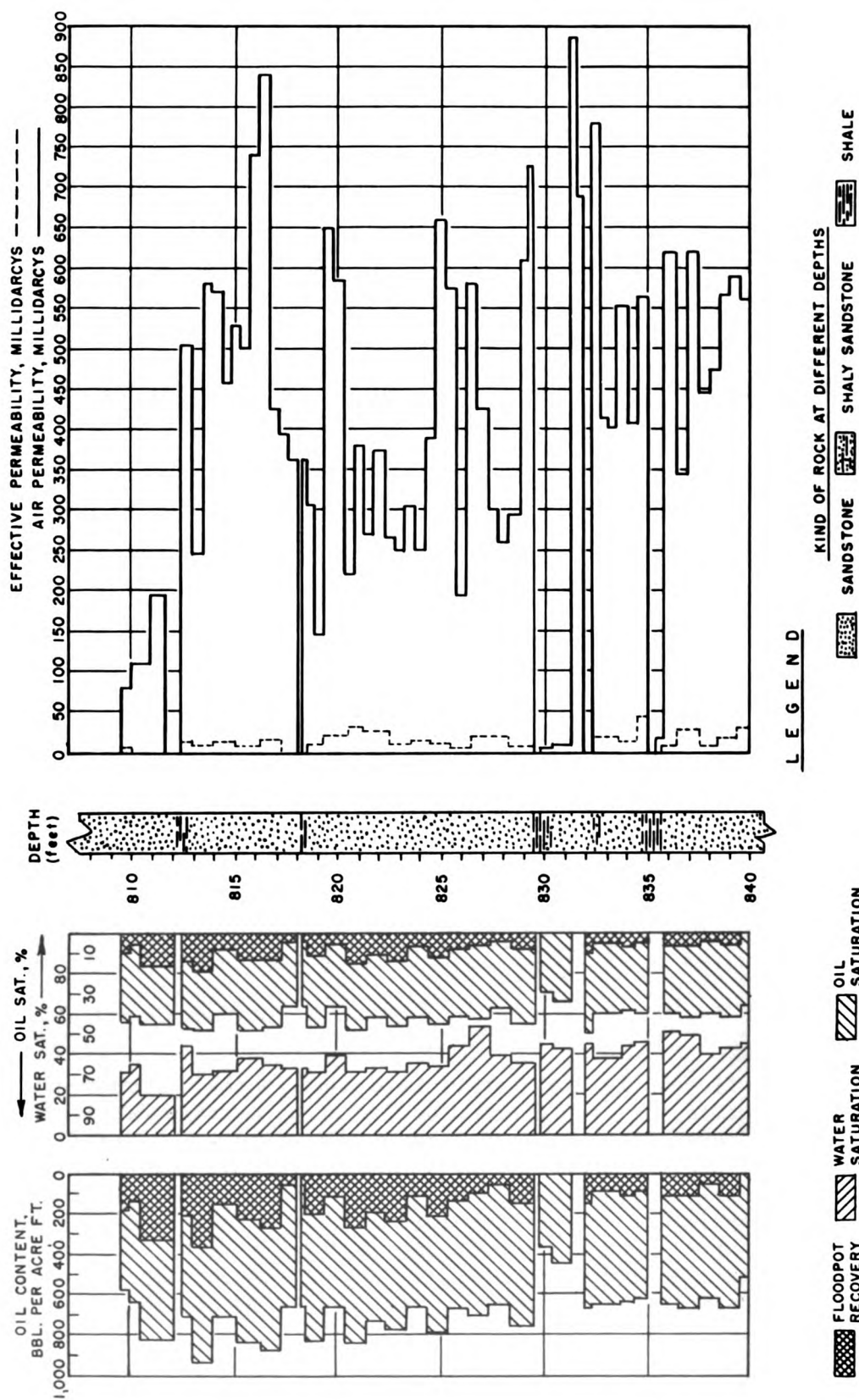


FIGURE 9. - Results of Core Analyses of Bartlesville Sandstone, Texas-Western Co.
 North Lease Block Project, Allen County, Kans.

History Before Flooding

Original development of the flooded leases occurred in 1915 and 1916. Eleven wells were drilled during this period; only 10 completed. Drilling difficulties necessitated abandoning one well. Production was by primary methods, and data are not available on the volume of oil produced. Five of the original wells were cleaned out and recompleted as producing wells in 1955 during the pilot flood.

Method of Completing and Operating Wells

The five old producing wells used in the expanded flood are equipped with tubing and rods. They were completed with 6-1/2-inch casing set at the top of the sand. These wells were reshot with 1-1/2 to 2 quarts of nitroglycerin per foot of sand and cleaned. They were pumped with a 20-foot, band-wheel power, driven by a gas engine until June 1957, when electrification of the lease was begun. Only one electric pumping unit was in service on November 1, 1957.

The input wells were completed with 4-inch pipe set at the top of the sand and cemented to the surface. These wells were shot with 1 to 1-1/2 quarts of nitroglycerin per foot of pay sand.

Water originally was injected into input wells at a rate of 2 barrels of water per foot of oil sand penetrated; however, when some degree of fill-up was obtained, the rate was maintained at 1 barrel of water per foot of sand. Wellhead pressures range from 40 to 60 p.s.i.

Source and Treatment of Water

Water for flooding is obtained from a well completed in the Arbuckle limestone at a depth of 1,028 feet. Water was pumped directly to the input wells in a closed system without chemical treatment or filtration; however, an open-type, water-treating plant is under construction. Table 5 shows results of mineral analyses of the brine.

TABLE 5. - Mineral analyses of injection waters, Texas-Western Co.
North Lease Block project, Allen County, Kans.

Ion or radical	Supply-well water	
	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	150	3.17
Magnesium (Mg)	76	2.65
Sodium (Na)	2,400	44.18
Carbonate (CO ₃)	0	0
Bicarbonate (HCO ₃)	561	3.89
Sulfate (SO ₄)	57	.50
Chloride (Cl)	3,820	45.61
Total solids	7,064	100.00
Hydrogen sulfide (H ₂ S)	None detected, faint odor	
Barium (Ba)	None	
Specific gravity	1,002	

Results of Flooding

From core analyses it is estimated that about 34,000 barrels would have been required to fill pore spaces on the original 5-acre pilot. By January 1, 1957, 24,000 barrels of water had been injected and 1,914 barrels of oil recovered for a water injected-oil produced ratio of 12.7:1. Individual wells had shown substantial increases in the rate of oil production, justifying expansion of the pilot project.

During 1957, failure of the old band-wheel power and delays in installing new pumping equipment resulted in erratic production rates. However, it is expected that the new pumping equipment and treating plant will increase oil-production rates and justify the expansion now in progress. By November 1, 1957, 40,000 barrels of water had been injected to recover more than 3,080 barrels of additional oil.

Summary of Operations

Texas-Western Co. North Lease Block project
Humboldt-Chanute field, Allen County, Kans.

Location - sec. 29, T. 26 S., R. 20 E.	Type of water - brine.
Sand flooded - Bartlesville.	Type of system - closed.
Depth to top of sand - 800 feet.	First injection - June 1955.
Average sand thickness - 19 feet.	First oil increase - July 1956.
Area flooded - 25 acres.	Status - active.
Well pattern - irregular.	Gravity of oil - 23° API.
	Viscosity - 176 cp. at 60° F.

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water injected - oil produced ratio
Dec. 31, 1955	5	1	3	131	4
Dec. 31, 1956	5	2	5	383	13
Oct. 31, 1957	25	9	9	123	13

Monthly record of water injected and oil produced, bbl.

Month	1955		1956		1957	
	Water injected	Oil produced	Water injected	Oil produced	Water injected	Oil produced
January			1,424	118	1,851	0
February			1,616	118	1,642	77
March			1,401	119	2,046	153
April			2,127	119	2,351	76
May			1,985	0	1,671	267
June			2,530	235	1,686	118
July	85	120	2,553	78	958	89
August	592	119	1,894	157	1,235	0
September	535	120	1,524	79	1,047	118
October	411	119	140	79	1,148	268
November	474	60	2,114	78		
December	684	119	2,314	77		
Total	2,781	657	21,622	1,257	15,635	1,166

	<u>Bbl.</u>
Water injected to November 1, 1957	40,038
Oil recovered by waterflooding to November 1, 1957	3,080

Veeder Supply & Development Co. Brown-Wilmoth project

The Brown-Wilmoth project of the Veeder Supply & Development Co. (fig. 10) in secs. 12 and 13, T. 34 S., R. 18 E., in the Edna field, Labette County, Kans., is a relatively new one, started in December 1954.

The formation flooded is the Bartlesville sand, which is at an average depth of 560 feet and ranges from 5 to 11 feet in thickness. Analyses of cores (fig. 11), taken with cable tools, show that the average permeability of the sand ranges from 83 to 141 millidarcys; some sections having permeability as high as 260 millidarcys. The average porosity is 16 percent. Oil saturation ranges from 32 to 55 percent and water saturation from 22 to 45 percent. When water injection was begun, the oil produced had a gravity of 26.1° API and a viscosity of 34.7 cp. at 100° F. An analyses of 2 crude-petroleum samples (items 5 and 5a), taken in 1956 and in 1957 during the flood, showed a gravity of 25.9° API and a decrease in absolute viscosity from 34.7 to 30.8 cp. at 100° F.

History Before Flooding

The discovery well was drilled in 1953; only five producing wells have been completed in the area. The oil-producing formation is of the "shoestring" type, and there has been little exploratory drilling to develop the producing area. Subsequent drilling has brought the number of wells drilled to 12, including 5 oil-producing wells, 4 water-input wells, 1 water-supply well, and 2 dry holes. The production-decline curve in figure 10 shows the oil-production history by primary methods and beginning December 1954, by water injection.

Method of Completing and Operating Wells

The oil wells were completed with 4-inch pipe set and cemented at the top of the oil sand. Each well was cored to aid in locating the best seat for the casing, as it was thought necessary to "case off" several coal veins just above the oil sand. The oil sand was fractured hydraulically using 150 to 200 barrels of oil and 5,000 to 7,000 pounds of sand in each well. The wells are equipped with 2-inch tubing, rods, and individual pumping units powered by 1-1/2-hp. electric motors.

The 4 input wells were completed with 4-inch pipe set and cemented at the top of the sand. The sand sections in each input well were shot with 20 quarts of nitroglycerin. The volume of water injected into each well is metered, and the rate is controlled by a valve at the wellhead. Electric clocks control the pumping periods, and heights of fluid levels in all wells are kept at a minimum.

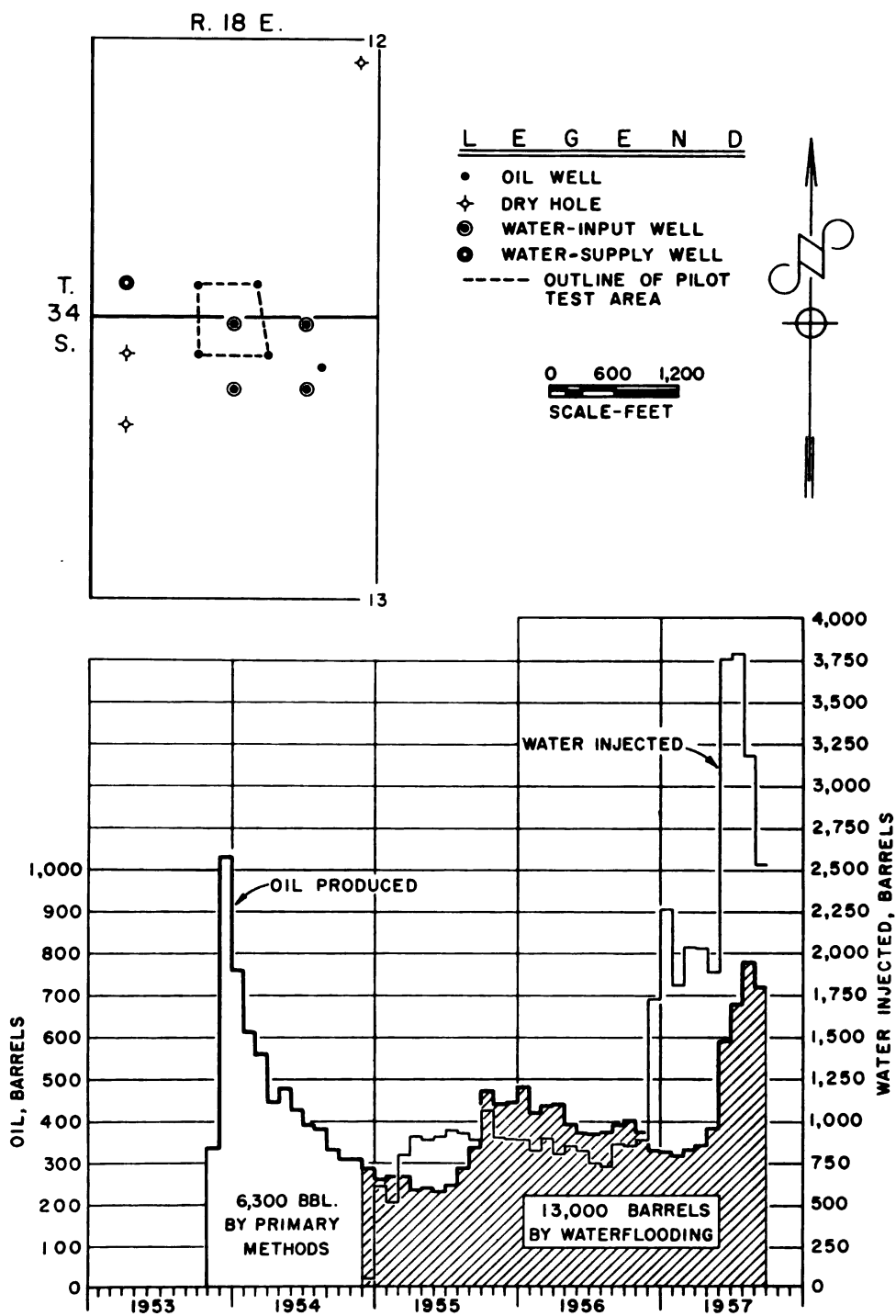


FIGURE 10. - Map and Production History of Veeder Supply & Development Co. Brown-Wilmoth Project, Labette County, Kans., Oct. 1, 1957.

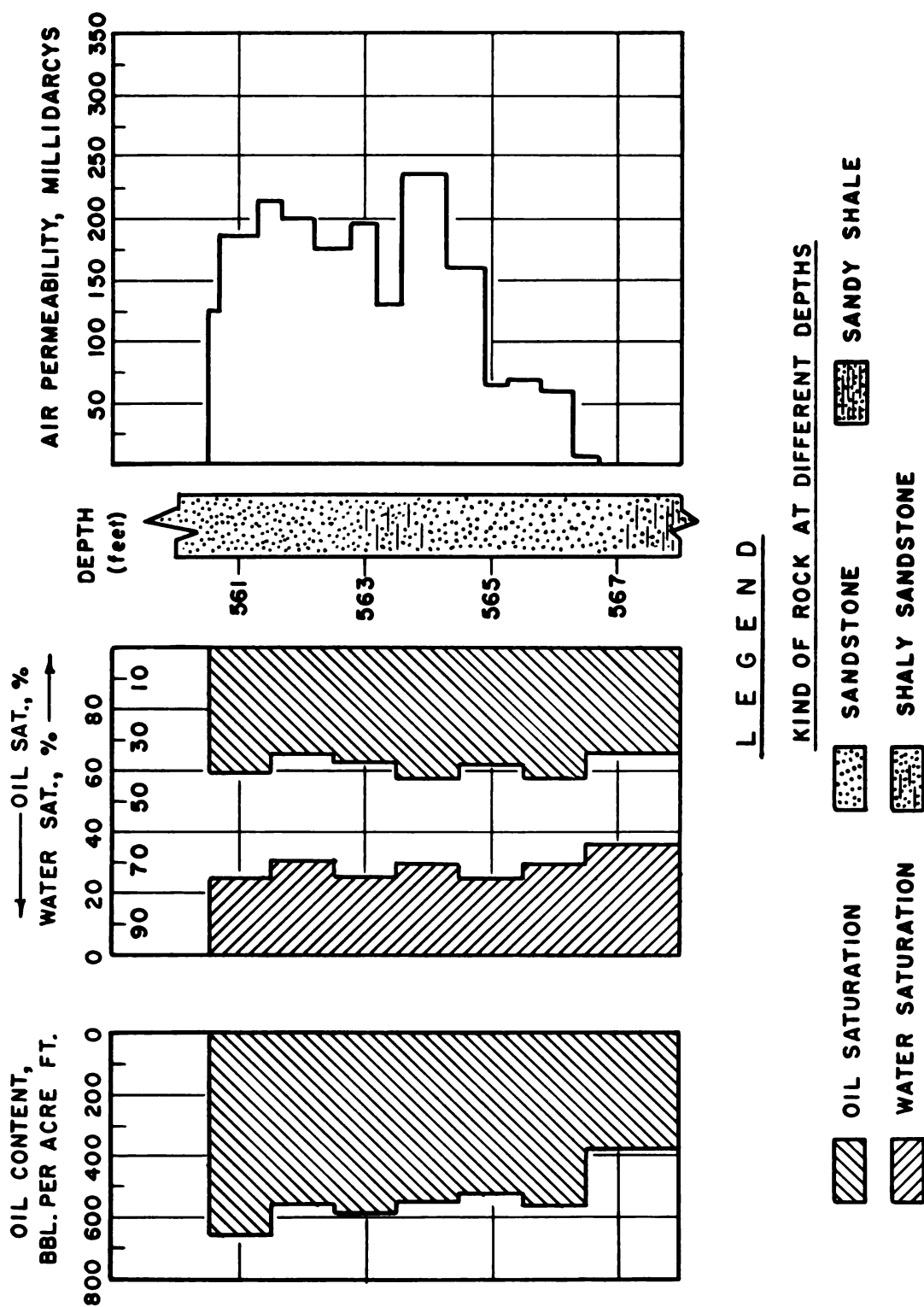


FIGURE 11. - Results of Core Analyses of Bartlesville Sandstone, Veeder Supply & Development Co. Brown-Wilmoth Project, Labette County, Kans.

Source and Treatment of Water

Water for flooding is now obtained from a well drilled into the Arbuckle formation to a depth of 1,026 feet in September 1956. The Arbuckle well is equipped with a large pumping unit that forces the water into the input wells at a pressure of 400 p.s.i. through a closed system. Previously, two wells completed in the Oswego limestone formation had supplied the needed brine but proved inadequate.

The rate of injection and the injection pressure can be regulated by controlling the speed and stroke of the unit on the supply well and by valves at each input wellhead. Approximately 1 pint of corrosion inhibitor per day is injected by a small chemical pump into the annulus between the casing and tubing of the water-supply well as "down-the-hole" treatment.

Mineral analyses of water samples from the project (table 6) show that the Arbuckle brine contains about one-third of the total solids in the produced brine and hydrogen sulfide.

TABLE 6. - Mineral analyses of injection waters, Veeder Supply & Development Co. Brown-Wilmoth project, Labette County, Kans.

Ion or radical	Supply-well water		Produced brine	
	P.p.m.	Reacting values, percent (Palmer)	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	238	4.68	1,530	7.28
Magnesium (Mg)	57	1.85	445	3.49
Sodium (Na)	2,500	43.47	9,460	39.23
Carbonate (CO ₃)	0	0	0	0
Bicarbonate (HCO ₃)	914	5.90	323	5.30
Sulfate (SO ₄)	0	0	trace	0
Chloride (Cl)	3,970	44.10	18,400	49.49
Total solids	7,679	100.00	30,158	100.00
Hydrogen sulfide (H ₂ S)	Detected		Detected	
Barium (Ba)	do.		20 p.p.m.	
Specific gravity 60° F.	1.004		1,026	

Results of Flooding

Comparatively slow injection rates have been maintained on the project to prevent channeling of water to adjacent oil wells. In July 1955, after only 4,600 barrels of Oswego limestone water had been injected into one well, rate of oil production from some surrounding wells gradually began to increase. From average core-analysis data, it is calculated that complete fill-up of the original inverted 5-spot should have required about 14,000 barrels of water. In November 1956 the rate of water injection was increased from about 820 barrels to about 2,000 barrels per month. Seven months later there was another marked increase in the rate of oil production. By October 1, more

than 13,000 barrels of oil had been recovered by the injection of 44,000 barrels of water, giving a water injected-oil produced ratio of 3.4 to 1. Although the flood is comparatively new, results have been very favorable, and the cost has been low.

Summary of Operations

Veeder Supply & Development Co. Brown-Wilmoth project

Edna field, Labette County, Kans.

Location - sec. 13, T. 34 S., R. 18 E.	Type of water - brine.
Sand flooded - Bartlesville.	Type of system - closed.
Depth to top of sand - 565 feet.	First injection - December 1954.
Average sand thickness - 6 feet.	First oil increase - July 1955.
Area flooded - 20 acres.	Status - active.
Well pattern - inverted 5-spot.	Gravity of oil - 26.1° API.
	Viscosity of oil - 34.7 cp. at 100° F.

Oil production by years, bbl.

1953	1,364	1956	4,697
1954 ^{1/}	5,235	1957	^{2/} 4,401
1955	3,663		

^{1/} Waterflooding begun.

^{2/} Figures for 9 months.

	<u>Bbl.</u>
Oil recovered by primary methods to December 1, 1954	6,319
Water injected to October 1, 1957	44,190
Oil recovered by waterflooding to October 1, 1957	13,041

Summary of waterflood performance

Date	Acres flooded	Active input wells	Active oil wells	Oil recovery, bbl. per acre	Cumulative water injected - oil produced ratio
Dec. 31, 1954	10	1	4	-	-
Dec. 31, 1955	10	1	4	394	3
Dec. 31, 1956	20	4	4	432	2
Sept. 30, 1957	20	4	5	652	3

Monthly record of water injected and oil produced, bbl.

	1954		1955	
	Water injected	Oil produced	Water injected	Oil produced
January			607	255
February			507	261
March			790	261
April			899	228
May			879	236
June			899	227
July			936	241
August			922	283
September			879	330
October			1,053	465
November			890	437
December	51	280	881	439
Total	51	280	10,142	3,663
Month	1956		1957	
January	871	475	2,252	319
February	819	410	1,804	306
March	886	431	2,025	324
April	796	434	2,023	337
May	841	386	1,877	378
June	809	366	3,754	584
July	738	363	3,790	670
August	720	368	3,174	773
September	852	385	2,529	710
October	842	392		
November	876	366		
December	1,719	321		
Total	10,769	4,697	23,228	4,401

Woodson Pipeline & Producing Co. Big Sandy Project

The Big Sandy project (fig. 12) of Woodson Pipeline & Producing Co. in secs. 14, 22, and 23, T. 26 S., R. 14 E., in the Big Sandy pool, Woodson County, Kans., is an accidental waterflood augmented recently by the disposal of produced brine. A water-conditioning plant, now under construction, will be used to develop leases for pattern flooding.

The formation flooded is the Bartlesville sand, which occurs at an average depth of 1,300 feet and has an average thickness of 40 feet. The sand body is lenticular, varying in width and thickness, and limits of production have not been defined. Analyses of cores (fig. 13) indicate that the average reservoir conditions were as follows: Porosity, 20 percent; permeability to air, 75 millidarcys (ranging from 0 to 227 millidarcys); average effective permeability to water, 4.6 millidarcys; oil saturation, 45 percent; and water saturation, 35 percent. Results of analyses of representative oil samples (items 6-6a), taken during the life of the flood, show a progressive increase in oil gravity from 22.1° to 23° API and a decrease in absolute viscosity from 82.7 to 63.8 cp. at 100° F.

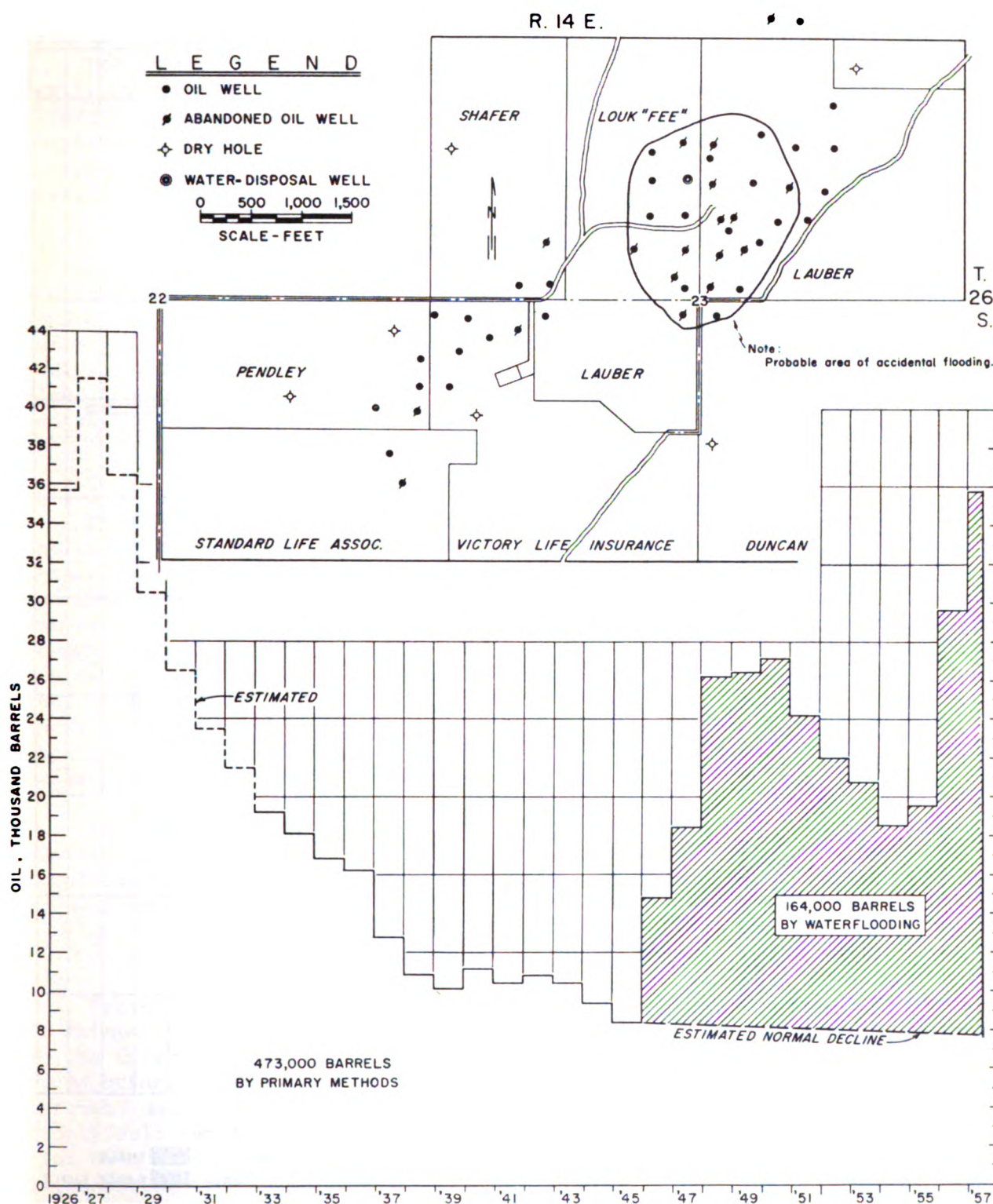


FIGURE 12. - Map and Production History of Woodson Pipeline & Producing Co.
Big Sandy Project, Woodson County, Kans., July 1, 1957.

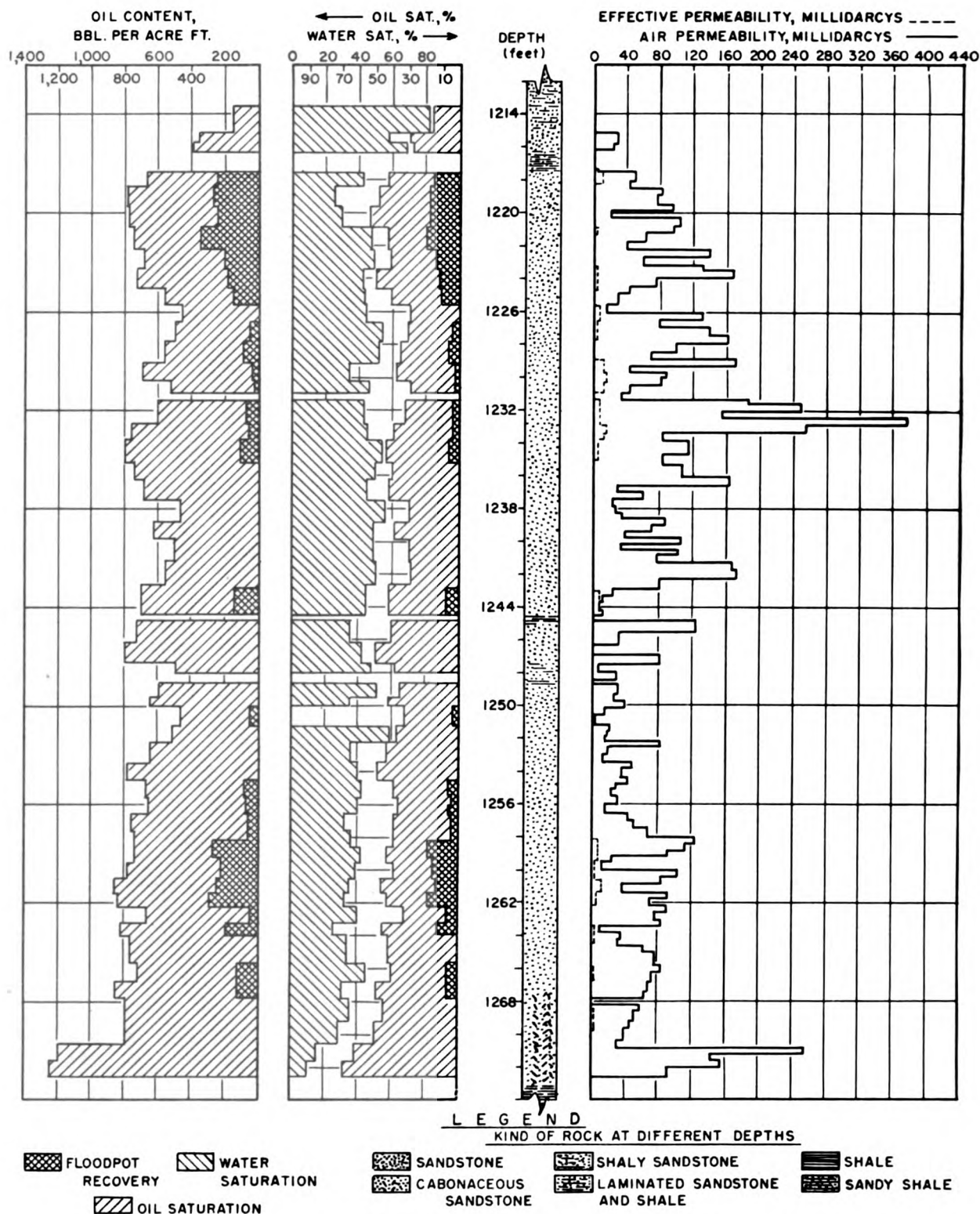


FIGURE 13. - Results of Core Analyses of Bartlesville Sandstone, Woodson Pipeline & Producing Co. Big Sandy Project, Woodson County, Kans.

History Before Flooding

The flooded properties were originally drilled in 1926. The wells initially produced as much as 300 barrels of oil daily. Early development was retarded, and lack of marketing facilities limited primary oil production from the lease. This situation eventually led to early abandonment of about half the original wells. Oil production has been by primary methods, although disposal of produced water in the Bartlesville sand was begun in 1956.

In 1945 the rate of oil production from 17 producing oil wells began to increase because of an accidental flood. In 1948 two new wells were drilled and cored to determine the efficiency of this accidental flood. Casings in several of six old wells were tested to locate the source of the extraneous water. The wells were reworked and recompleted as oil wells. In 1956 four additional wells were drilled and cored in further attempts to locate the flood front and profit from the accidental flood. One old well was reopened and recompleted to serve as an injection well for the produced brine.

Method of Completing and Operating Wells

The single water-input well was completed with 5-1/2-inch casing set on the top of the sand and cemented to the surface. The old producing wells that were reworked were reshot with 2 to 3 quarts of nitroglycerin per foot of sand and thoroughly cleaned. Two of the old wells were completed with 2-inch pipe set at the top of the pay sand and cemented with 30 to 50 sacks of cement. Enough cement was used to raise the level of the cement above all water-bearing sands. The remainder of the annulus was then filled to the surface with mud. The wells are pumped with individual, electrically operated pumping jacks with 1-inch pipe and insert barrels. Seven additional old wells were recompleted with 4-inch pipe and cemented with 300 sacks of cement. These wells are pumped with standard 2-inch equipment.

The new oil wells were completed with 4-inch pipe cemented in a manner similar to that used in other producing wells. These wells, however, were completed by being hydraulically fractured with lease crude oil and 4,000 to 6,000 pounds of sand.

Source and Treatment of Water

Present source of water is the brine produced with the oil. The brine is skimmed to remove all traces of oil and flows by gravity from the separator to the injection well. Table 7 shows the results of an analysis of the produced brine. Approximately 35 barrels was injected daily from June 1956 through June 1957, totaling about 13,000 barrels. The location of a water-supply well has been staked, and several tanks have been set for the construction of a water-conditioning system. Only tanks will be used to contain the brine during treatment.

Results of Flooding

Although only 13,000 barrels of water has been injected, results from the accidental flooding, augmented by brine disposal, are excellent, as shown by the production-decline curve in figure 12. The new drilling and remedial work

have been important factors. However, increased productivity of the wells is a result of the water drive (the formation pressure has increased to about 30 p.s.i. in the affected area of the field). It is estimated that between 2.5 and 3 million barrels of oil could be recovered by injecting water into the reservoir.

TABLE 7. - Mineral analyses of injection waters, Woodson Pipeline & Producing Co. Big Sandy project, Woodson County, Kans.

Ion or radicals	Produced brine	
	P.p.m.	Reacting values, percent (Palmer)
Calcium (Ca)	3,470	5.96
Magnesium (Mg)	1,495	4.20
Sodium (Na)	26,600	39.84
Carbonate (CO ₃)	0	0
Bicarbonate (HCO ₃)	165	.09
Sulfate (SO ₄)	0	0
Chloride (Cl)	51,400	49.91
Total solids	83,120	100.00
Hydrogen sulfide (H ₂ S)	None	
Barium (Ba)	192 p.p.m.	
Specific gravity	1,059	

Summary of Operations

Woodson Pipeline & Producing Co. Big Sandy project Big Sandy field, Woodson County, Kans.

Location - secs. 14, 22, and 23, T. 26 S., R. 14 E.	Type of water - brine.
Sand flooded - Bartlesville.	Type of system - closed.
Depth to top of sand - 1,300 feet.	First injection - unknown.
Average sand thickness - 40 feet.	First increase - 1945.
Productive area - 120 acres.	Status - active.
Well pattern - irregular.	Gravity of oil - 22.1° API.
	Viscosity of oil - 63.7 cp. at 100° F.

Oil produced by years, bbl.

1926	35,700	1937	12,805	1948	26,273
1927	41,500	1938	10,896	1949	26,448
1928	31,500	1939	10,896	1950	27,127
1929	30,500	1940	11,194	1951	24,315
1930	26,500	1941	10,445	1952	22,058
1931	23,500	1942	10,833	1953	20,770
1932	21,500	1943	10,405	1954	18,512
1933 ^{1/}	19,214	1944	9,369	1955	19,571
1934	18,147	1945	8,369	1956	29,637
1935	16,869	1946	14,858	1957	^{2/} 17,865
1936	16,240	1947	18,460		

^{1/} Early production data estimated from incomplete records.

^{2/} First 6 months figures.

	<u>Bbl.</u>
Oil recovered by primary methods, estimated to July 1, 1957	473,000
Oil recovered by natural waterflooding and disposal to July 1, 1957.	164,000

ANALYSES OF CRUDE-OIL SAMPLES

The following (items 1-6a) summarize characteristics of the crude-oil samples analyzed:

Item 1

Bureau of Mines Bartlesville Laboratory Sample 56106
Sampled September 12, 1956
LaCyme-Cadmus field Kansas
Peru (Lower) sand Linn County
219-239 feet 20S-23E-6th

IDENTIFICATION

GENERAL CHARACTERISTICS

Specific gravity 0.896 A. P. I. gravity 26.4 Pour point, ° F. below 5
Sulfur percent 0.59 Color brownish black
Saybolt Universal viscosity at 100° F. 216 sec. (40.9 sp.) Nitrogen, percent, 0.221
130° F., 103 sec. (18.2 cp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1—Distillation at atmospheric pressure, ... 744 ... mm. Hg
First drop, ... 29 ... ° C. (84 ... ° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. gr., 60/60° F.	A. P. I.	C. I.	Refractive N _d at 20° C.	Specific dispersion	S. U. 100° F.	Cloud test, ° F.
1	122	0.3	0.3	0.658	83.6	—	—	—	—	—
2	167	1.3	1.6	.634	73.3	17	1.33169	125.2	—	—
3	218	2.8	4.4	.707	68.6	15	1.40722	121.2	—	—
4	257	3.2	7.6	.732	61.8	18	1.41818	128.5	—	—
5	302	3.3	10.9	.752	56.7	20	1.42822	128.2	—	—
6	347	3.7	14.6	.771	52.0	22	1.43852	129.6	—	—
7	392	4.0	18.6	.791	47.4	25	1.44742	130.8	—	—
8	437	3.8	22.4	.809	43.4	28	1.45552	133.1	—	—
9	482	4.7	27.1	.826	39.8	31	1.46459	140.2	—	—
10	527	5.8	32.9	.842	36.6	34	—	—	—	—

STAGE 2—Distillation continued at 40 mm. Hg

11	392	2.4	35.3	0.860	33.0	38	1.47493	146.1	1.2	Below 5.
12	437	5.8	41.1	.869	31.3	39	1.47870	148.1	48	15
13	482	5.1	46.2	.880	29.3	41	1.48565	153.9	62	35
14	527	5.1	51.3	.894	26.8	44	1.49315	153.4	95	55
15	572	6.1	57.4	.906	24.7	47	1.49931	152.3	185	70
Residue		42.1	99.5	.991	11.3					

Rambottom carbon residue: Residue, 5.8 percent; crude, 2.7 percent.
Equivalent Conradson carbon residue: Residue, 1.7 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	A. P. I.	Viscosity
Light gasoline	4.4	0.699	70.9	
Total gasoline and naphtha	18.6	0.719	57.7	
Kerosene distillate	3.8	.809	43.4	
Gas oil	16.7	.846	35.8	
Nonviscous lubricating distillate	10.0	.871-.894	31.0-26.8	50-100
Medium lubricating distillate	6.2	.894-.908	26.8-24.3	100-200
Viscous lubricating distillate	2.1	.908-.912	24.3-23.7	Above 200
Residue	42.1	.991	11.3	
Distillation loss	.5			

Item 1a

Bureau of Mines Bartlesville Laboratory Sample 57078
Sampled September 12, 1957
LaCyme-Cadmus field Kansas
Peru sand Linn County
221-229 feet 20S-23E-6th

IDENTIFICATION

GENERAL CHARACTERISTICS

Specific gravity 0.896 A. P. I. gravity 26.4 Pour point, ° F. below 5
Sulfur percent 0.56 Color brownish black
Saybolt Universal viscosity at 100° F. 194 sec. (36.7 sp.) Nitrogen, percent, 0.205
130° F., 117 sec. (19.1 cp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1—Distillation at atmospheric pressure, ... 716 ... mm. Hg
First drop, ... 42 ... ° C. (108 ... ° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. gr., 60/60° F.	A. P. I.	C. I.	Refractive N _d at 20° C.	Specific dispersion	S. U. 100° F.	Cloud test, ° F.
1	122	2.3	2.3	0.668	80.3	—	1.37641	125.9	—	—
2	167	2.5	4.8	.720	69.0	21	1.39920	119.7	—	—
3	212	3.6	8.4	.740	59.7	22	1.40994	124.6	—	—
4	257	3.9	12.3	.761	54.4	24	1.42163	124.3	—	—
5	302	3.0	15.3	.780	49.9	26	1.43173	125.8	—	—
6	347	3.5	18.8	.797	46.0	28	1.44045	127.7	—	—
7	392	4.6	23.4	.814	42.3	31	1.44955	128.8	—	—
8	437	4.8	28.2	.831	38.8	33	1.45832	136.5	—	—
9	482	5.9	34.1	.848	35.4	37	1.46709	139.2	—	—
10	527								—	—

STAGE 2—Distillation continued at 40 mm. Hg

11	392	1.1	35.2	0.859	33.2	38	1.47600	—	45	Below 5.
12	437	2.1	40.3	.872	30.8	40	1.47929	—	48	20
13	482	6.1	46.4	.886	28.2	42	1.49557	—	62	50
14	527	6.0	52.4	.896	26.4	45	1.49365	—	100	66
15	572	6.1	58.5	.911	23.8	49	—	—	210	76
Residue		41.0	99.5	.994	10.9					

Rambottom carbon residue: Residue, 4.0 percent; crude, 1.8 percent.
Equivalent Conradson carbon residue: Residue, 5.4 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	A. P. I.	Viscosity
Light gasoline	4.8	0.695	72.1	
Total gasoline and naphtha	18.8	0.750	57.2	
Kerosene distillate	4.6	.814	42.3	
Gas oil	15.2	.848	35.4	
Nonviscous lubricating distillate	10.8	.873-.896	30.6-26.4	50-100
Medium lubricating distillate	5.6	.896-.910	26.4-24.0	100-200
Viscous lubricating distillate	3.2	.910-.919	24.0-22.5	Above 200
Residue	41.0	.944	18.4	
Distillation loss	.5			

Item 2

Bureau of Mines
Sample 54017
Bartlesville
Laboratory
February 17, 1954

IDENTIFICATION

Hepler field
Tucker sand
600-620 feet

Kansas
Bourbon County
278-228-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.897
Sulfur, percent, 0.58
Saybolt Universal viscosity at 100° F., 113 sec. (18.2 cp.)
A. P. I. gravity, 26.3°
Four point, ° F., below 5
Color, brownish black
Nitrogen, percent, 0.189

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brass 1—Distillation at atmospheric pressure, 71.6 mm. Hg
First drop, 32° C. (90° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. I., 60° F.	C. I.	Refractive index, Na at 20° C.	Specific dispersion	S. U. viscosity, 100° F.	Cloud test, ° F.
1	128	1.2	1.2	0.675	78.1		1.38026	121.6		
2	167	1.3	2.5				1.40488	124.9		
3	212	2.2	4.7				1.43509	128.9		
4	267	2.6	7.3				1.45259	128.1		
5	308	3.2	10.5				1.45365	127.6		
6	347	3.2	13.7				1.44597	131.5		
7	392	4.2	17.9				1.4498	134.9		
8	437	4.6	22.5				1.46349	140.8		
9	482	5.8	28.3							
10	527									

Brass 2—Distillation continued at 40 mm. Hg

11	592	3.2	31.5	0.857	33.6	37			40	Below 5
12	487	6.1	37.6			38			46	20
13	488	5.5	43.1			40			52	35
14	527	5.6	48.7			41			86	55
15	578	7.0	55.7			45			175	70
Residue		44.3	100.0							

Ramifications carbon residues: Residue, 11.5 percent; crude, 5.6 percent.
Equivalent Conradson carbon residues: Residue, 11.0 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	A. P. I.	Viscosity
Light gasoline	2.5	0.675	78.1	
Total gasoline and naphtha	13.7	0.745	58.4	
Kerosene distillate	8.8		42.1	
Gas oil	13.9		34.6	
Nonviscous lubricating distillate	10.5		27.5	
Medium lubricating distillate	7.1		24.7	
Viscous lubricating distillate	1.7		24.0	
Residue	44.3		13.0	
Distillation loss	0			

Item 2a

Bureau of Mines
Sample 56105
Bartlesville
Laboratory
September 13, 1956

IDENTIFICATION

Hepler field
Tucker sand
600-614 feet

Kansas
Bourbon County
278-228-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.898
Sulfur, percent, 0.55
Saybolt Universal viscosity at 100° F., 215 sec. (40.0 cp.)
A. P. I. gravity, 26.1°
Four point, ° F., below 5
Color, brownish black
Nitrogen, percent, 0.188

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brass 1—Distillation at atmospheric pressure, 71.4 mm. Hg
First drop, 52° C. (126° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. I., 60° F.	C. I.	Refractive index, Na at 20° C.	Specific dispersion	S. U. viscosity, 100° F.	Cloud test, ° F.
1	128	0.5	0.5	0.693	78.7		1.39975			
2	167	1.3	1.8				1.41676			
3	212	2.2	4.0				1.42524			
4	267	2.6	6.6				1.43572			
5	308	3.1	9.7				1.44577			
6	347	3.3	13.0				1.45492			
7	392	4.3	17.3				1.46368			
8	437	4.5	21.8							
9	482	6.4	28.2							
10	527									

Brass 2—Distillation continued at 40 mm. Hg

11	592	3.7	31.9	0.856	33.8	37			42	Below 5
12	487	5.3	37.2			37			49	20
13	488	6.5	43.7			41			64	30
14	527	5.7	49.4			45			100	50
15	578	7.1	56.5			49			260	65
Residue		44.8	98.6							

Ramifications carbon residues: Residue, 6.4 percent; crude, 2.9 percent.
Equivalent Conradson carbon residues: Residue, 6.1 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	A. P. I.	Viscosity
Light gasoline	1.8	0.701	70.4	
Total gasoline and naphtha	8.0		58.2	
Kerosene distillate	9.6		41.9	
Gas oil	13.1		33.0	
Nonviscous lubricating distillate	13.0		26.8	
Medium lubricating distillate	6.1		24.5	
Viscous lubricating distillate	4.8		22.8	
Residue	44.8		12.6	
Distillation loss	1.4			

Item 2b

Bureau of Mines .. Bartlesville .. Laboratory .. Sample .. 57077 ..
Sample .. 57077 ..Bureau of Mines .. Bartlesville .. Laboratory .. Sample .. 56109 ..
Sample .. 56109 ..

IDENTIFICATION

IDENTIFICATION

Hepler field
Tucker sand
600-620 feetNecho Falls field
Squirrel sand
950-960 feetKansas
Woodson County
23S-16E-6th

Laboratory

Sample

October 12, 1956

GENERAL CHARACTERISTICS

GENERAL CHARACTERISTICS

Specific gravity, 0.901 .. A. P. I. gravity, 25.6° .. Pour point, ° F., below 5 ..
Sulfur, percent, 0.55 .. Color, brownish black ..
Saybolt Universal viscosity at 100° F., 228 sec. (43.5 cp.) .. Nitrogen, percent, 0.215 ..
130° F., 115 sec. (20.2 cp.) ..Specific gravity, 0.893 .. A. P. I. gravity, 27.0° .. Pour point, ° F., below 5 ..
Sulfur, percent, 0.49 .. Color, brownish black ..
Saybolt Universal viscosity at 100° F., 221 sec. (41.8 cp.) .. Nitrogen, percent, 0.217 ..
130° F., 126 sec. (20.7 cp.) ..

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Strain 1—Distillation at atmospheric pressure, 746 mm. Hg
First drop, 50 .. ° C. (122 .. ° F.)Strain 1—Distillation at atmospheric pressure, 751 mm. Hg
First drop, 33 .. ° C. (91 .. ° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr., 60/60° F.	* A. P. I., 60° F.	C. I.	Refractive index, N _D at 20° C.	Specific dispersion	S. U. index, 100° F.	Cloud temp., ° F.
1	122	0.6	0.6	0.707	68.6	-	1.40028	123.3		
2	167	0.8	1.4	0.729	62.6	-	1.41534	125.8		
3	212	2.1	3.5	0.748	57.7	18	1.42665	129.7		
4	257	2.4	5.9	0.770	52.3	22	1.43663	130.0		
5	302	3.3	9.2	0.790	47.6	25	1.44613	133.2		
6	347	2.6	11.8	0.810	43.2	29	1.45530	135.0		
7	392	4.1	15.9	0.827	39.6	34	1.46428	141.3		
8	437	4.5	20.4	0.843	36.4					
9	482	5.8	26.2							
10	527									

Strain 2—Distillation continued at 40 mm. Hg

11	392	3.5	29.7	0.856	33.8	37	1.47428	150.5	43	14
12	437	5.8	35.5	0.868	31.5	38	1.47906		49	24
13	482	7.1	42.6	0.883	28.8	42	1.48676		68	46
14	527	6.0	48.6	0.899	25.9	47	1.49397		115	60
15	572	8.2	56.8	0.915	23.1	51			280	72
Residue		41.2	98.0	0.966	12.0					

Ramabottom carbon residue: Residue, 6.2 percent; crude, 2.8 percent.
Equivalent Conradson carbon residue: Residue, 8.2 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	* A. P. I.	Viscosity
Total gasoline and naphtha	11.8	0.707	68.6	
Kerosene distillate	4.1	0.755	55.9	
Gas oil	17.2	0.810	43.2	
Nonviscous lubricating distillate	10.5	0.869	31.3-26.8	50-100
Medium lubricating distillate	5.7	0.894	26.8-24.5	100-200
Viscous lubricating distillate	7.5	0.907	24.5-21.6	Above 200
Residue	41.2	0.966	12.0	
Distillation loss	2.0			

Item 3

Bureau of Mines .. Bartlesville .. Laboratory .. Sample .. 56109 ..
Sample .. 56109 ..Bureau of Mines .. Bartlesville .. Laboratory .. Sample .. 56109 ..
Sample .. 56109 ..

IDENTIFICATION

IDENTIFICATION

Necho Falls field
Squirrel sand
950-960 feetKansas
Woodson County
23S-16E-6th

Laboratory

Sample

October 12, 1956

GENERAL CHARACTERISTICS

GENERAL CHARACTERISTICS

Specific gravity, 0.893 .. A. P. I. gravity, 27.0° .. Pour point, ° F., below 5 ..
Sulfur, percent, 0.49 .. Color, brownish black ..
Saybolt Universal viscosity at 100° F., 221 sec. (41.8 cp.) .. Nitrogen, percent, 0.217 ..
130° F., 126 sec. (20.7 cp.) ..Specific gravity, 0.893 .. A. P. I. gravity, 27.0° .. Pour point, ° F., below 5 ..
Sulfur, percent, 0.49 .. Color, brownish black ..
Saybolt Universal viscosity at 100° F., 221 sec. (41.8 cp.) .. Nitrogen, percent, 0.217 ..
130° F., 126 sec. (20.7 cp.) ..

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Strain 1—Distillation at atmospheric pressure, 751 mm. Hg
First drop, 33 .. ° C. (91 .. ° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr., 60/60° F.	* A. P. I., 60° F.	C. I.	Refractive index, N _D at 20° C.	Specific dispersion	S. U. index, 100° F.	Cloud temp., ° F.
1	122	0.8	0.8	0.649	86.5	-	1.39242	121.9		
2	167	2.0	2.8	0.679	76.9	12	1.41455	126.2		
3	212	1.6	4.4	0.706	68.9	15	1.42547	128.8		
4	257	3.2	7.6	0.727	63.1	16	1.43570	128.1		
5	302	2.7	10.3	0.745	58.4	17	1.44471	133.7		
6	347	3.5	13.8	0.767	53.0	20	1.45451	140.2		
7	392	2.8	16.6	0.787	48.3	23	1.46329			
8	437	3.6	20.2	0.806	44.1	27				
9	482	4.6	24.8	0.821	40.9	29				
10	527	5.3	30.1	0.840	37.0	33				

Strain 2—Distillation continued at 40 mm. Hg

11	392	2.8	32.9	0.858	33.4	37	1.47330	144.0	43	Below 5
12	437	5.2	38.1	0.866	31.9	37	1.47787	143.7	47	20
13	482	5.2	43.3	0.881	29.1	41	1.48595		63	35
14	527	5.3	48.6	0.896	26.4	45	1.49285		100	50
15	572	6.0	54.6	0.906	24.7	47	1.49955		210	65
Residue		44.9	99.5	0.977	13.3					

Ramabottom carbon residue: Residue, 4.9 percent; crude, 2.4 percent.
Equivalent Conradson carbon residue: Residue, 6.6 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	* A. P. I.	Viscosity
Total gasoline and naphtha	16.6	0.683	75.7	
Kerosene distillate	8.2	0.737	60.5	
Gas oil	11.8	0.814	42.3	
Nonviscous lubricating distillate	9.4	0.852	34.8	
Medium lubricating distillate	5.2	0.869	31.3-26.4	50-100
Viscous lubricating distillate	3.4	0.896	26.4-24.9	100-200
Residue	44.9	0.977	13.3	Above 200
Distillation loss	0.5			

Item 3a

Bureau of Mines Bartlesville Laboratory Sample
25079
Sampled
September 11, 1957

IDENTIFICATION

Necho Falls field
Squirrel sand
950-960 feet

Kansas
Woodson County
238-168-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.894 A. P. I. gravity, 26.8° Four point, ° F., below 5
Sulfur, percent 0.50 Color, brownish black
Saybolt Universal viscosity at 100° F., 179 sec. (33.7 cp.) Nitrogen, percent, 0.201
130° F., 107 sec. (11.5 cp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brain 1—Distillation at atmospheric pressure, 746 mm. Hg
First drop, 30 ° C. (86 ° F.)

Fraction No.	Cat. temp., ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. I. 60° F.	C. I.	Refractive index N _D at 30° C.	Specific dispersion	S. U. vis., 100° F.	Cloud temp., ° F.
1	132	0.7	0.7	0.849	86.5	-	1.37759	122.1	-	-
2	167	3.1	3.8	0.676	77.8	10	1.37759	122.1	-	-
3	213	4.0	7.8	0.723	64.2	23	1.40204	127.5	-	-
4	257	1.4	9.2	0.741	59.5	22	1.41361	132.2	-	-
5	308	2.4	11.6	0.759	54.9	23	1.42719	130.3	-	-
6	347	3.2	14.8	0.770	52.3	22	1.43686	131.2	-	-
7	382	2.8	17.6	0.789	47.8	24	1.44632	131.8	-	-
8	437	3.7	21.3	0.808	43.0	31	1.45730	138.9	-	-
9	482	4.6	25.9	0.825	40.0	31	1.46834	141.2	-	-
10	527	5.3	31.2	0.841	36.8	33	1.48034	141.2	-	-

Brain 2—Distillation continued at 40 mm. Hg

11	582	2.3	33.5	0.856	33.8	37	1.47431	-	42	18
12	587	5.7	39.2	0.866	31.9	37	1.47790	-	47	24
13	582	5.0	44.2	0.881	29.1	41	1.48547	-	62	40
14	527	4.8	49.0	0.894	26.8	44	-	-	58	50
15	578	6.4	55.4	0.905	24.9	46	-	-	192	62
Residuum		43.8	99.2	0.931	12.7	-	-	-	-	-

Residuum carbon residue: Residuum, 6.4 percent; crake, 3.1 percent.
Equivalent Conradson carbon residue: Residuum, 8.4 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	A. P. I.	Viscosity
Total gasoline and naphtha	17.6	0.737	60.5	-
Kerosene distillate	8.3	0.817	41.7	-
Gas oil	11.6	0.852	34.6	-
Nonviscous lubricating distillate	9.1	0.869-0.894	31.3-26.8	60-100
Medium lubricating distillate	5.9	0.899-0.906	26.8-24.7	100-200
Viscous lubricating distillate	2.7	0.908-0.911	24.7-23.8	Above 200
Residuum	43.8	0.931	12.7	-
Distillation loss		-	-	-

Item 4

Bureau of Mines Bartlesville Laboratory Sample
56100
Sampled
September 6, 1956

IDENTIFICATION

Rumboldt-Chanute field
Bartlesville sand
800-830 feet

Kansas
Allen County
268-208-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.917 A. P. I. gravity, 22.8° Four point, ° F., below 5
Sulfur, percent 0.60 Color, brownish black
Saybolt Universal viscosity at 100° F., 312 sec. (60.7 cp.) Nitrogen, percent, 0.176
130° F., 168 sec. (29.8 cp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brain 1—Distillation at atmospheric pressure, 744 mm. Hg
First drop, 74 ° C. (165 ° F.)

Fraction No.	Cat. temp., ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. I. 60° F.	C. I.	Refractive index N _D at 30° C.	Specific dispersion	S. U. vis., 100° F.	Cloud temp., ° F.
1	132	1.88	1.88	0.750	57.2	-	1.43968	126.1	-	-
2	167	0.9	2.78	0.762	54.2	32	1.44853	129.6	-	-
3	213	1.3	4.08	0.781	49.7	34	1.45718	134.9	-	-
4	257	1.8	5.88	0.799	45.6	32	1.46588	141.4	-	-
5	308	2.2	8.08	0.814	42.3	36	1.47431	-	-	-
6	347	2.6	10.68	0.832	38.0	39	1.48289	-	-	-
7	382	3.6	14.28	0.844	34.2	40	1.49150	-	-	-
8	437	4.1	18.38	0.852	34.6	39	1.47762	148.5	41	Below 5
9	482	6.5	24.88	0.863	32.8	39	1.48175	151.6	47	10
10	527	6.5	31.38	0.872	30.8	40	1.48566	152.0	64	25
11	582	2.8	34.18	0.882	27.7	45	1.49568	167.6	100	40
12	587	7.0	41.18	0.897	26.3	49	1.50229	-	200	55
13	582	5.5	46.68	0.907	24.9	-	-	-	-	-
14	527	7.3	53.98	0.917	23.3	-	-	-	-	-
15	578	4.3	58.28	0.927	21.3	-	-	-	-	-
Residuum		48.3	99.5	0.937	13.3	-	-	-	-	-

Brain 2—Distillation continued at 40 mm. Hg

11	582	2.8	55.4	0.863	32.8	39	1.47762	148.5	41	Below 5
12	587	7.0	62.4	0.872	30.8	40	1.48175	151.6	47	10
13	582	5.5	67.9	0.882	27.7	45	1.48566	152.0	64	25
14	527	7.3	75.2	0.897	26.3	49	1.49568	167.6	100	40
15	578	4.3	79.5	0.907	24.9	-	-	-	200	55
Residuum		48.3	99.5	0.937	13.3	-	-	-	-	-

Residuum carbon residue: Residuum, 5.4 percent; crake, 2.0 percent.
Equivalent Conradson carbon residue: Residuum, 7.2 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	A. P. I.	Viscosity
Total gasoline and naphtha	8.2	0.750	57.2	-
Kerosene distillate	9.7	0.786	49.7	-
Gas oil	21.3	0.852	34.6	-
Nonviscous lubricating distillate	11.5	0.875-0.897	30.2-26.3	60-100
Medium lubricating distillate	6.4	0.897-0.910	26.3-24.0	100-200
Viscous lubricating distillate	3.6	0.910-0.917	24.0-22.8	Above 200
Residuum	48.3	0.937	13.3	-
Distillation loss		-	-	-

Item 4a

Bureau of Mines Bartlesville Laboratory
Sample 57086
September 26, 1957

IDENTIFICATION

Humbolt-Chanute field
Bartlesville sand
800 - 840 feet

Kansas
Allen County

GENERAL CHARACTERISTICS

Specific gravity, 0.915
Sulfur, percent, 0.62
Saybolt Universal viscosity at 100° F., 138 sec. (26.7 cp.)
Four point, ° F., below 5
Color, brownish black
Nitrogen, percent, 0.186

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

746 mm. Hg
First drop, 60° C. (140° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. L. 60° F.	C. I.	Refractive index N _D at 20° C.	Specific dispersion	S. U. vis., 100° F.	Cloud test, ° F.
1	128	1.0	1.0	0.750	57.2	-				
2	167	1.5	2.5	0.761	54.4	32				
3	212	1.5	4.0	0.760	49.9	38				
4	267	2.3	6.3	0.800	45.7	36				
5	302	2.3	8.6	0.818	41.2	38	1.42774	127.9		
6	347	2.1	10.7	0.831	38.8	39	1.44804	131.8		
7	392	3.1	13.8	0.841	36.4	39	1.45687	136.1		
8	437	4.6	18.4	0.843	34.4	40	1.46368	143.3		
9	482	5.9	24.3	0.854	34.2	40	1.47019	144.8		
10	527									

800 mm. Hg
First drop, 60° C. (140° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. L. 60° F.	C. I.	Refractive index N _D at 20° C.	Specific dispersion	S. U. vis., 100° F.	Cloud test, ° F.
11	392	3.6	25.9	0.861	32.8	39	1.47667	-	41	16
12	437	5.6	31.5	0.876	30.0	42	1.48197	-	48	28
13	482	5.8	37.3	0.892	27.7	45	1.48951	-	65	38
14	527	6.5	43.8	0.907	24.3	50	1.49747	-	110	54
15	572	7.0	50.8	0.914	23.3	51	-	-	230	65
Residuum		46.7	98.5	0.978	13.2					

Ramabottom carbon residue: Residuum, 4.9 percent; crude, 2.4 percent.
Equivalent Conradson carbon residue: Residuum, 5.6 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	A. P. L.	Viscosity
Total gasoline and naphtha	1.0	0.750	57.2	
Kerosene distillate	8.7	0.788	48.1	
Gas oil	21.3	0.853	34.4	
Nonviscous lubricating distillate	10.3	0.877-0.903	29.9-25.2	50-100
Medium lubricating distillate	6.4	0.903-0.912	25.2-23.7	100-200
Viscous lubricating distillate	5.1	0.912-0.917	23.7-22.8	Above 200
Residuum	46.7	0.978	13.2	
Distillation loss	1.5			

Item 5

Bureau of Mines Bartlesville Laboratory
Sample 56101
September 7, 1956

IDENTIFICATION

Bina field
Bartlesville sand
520-532 feet

Kansas
Labette County
348-188-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.899
Sulfur, percent, 0.56
Saybolt Universal viscosity at 100° F., 183 sec. (34.7 cp.)
Four point, ° F., below 5
Color, brownish black
Nitrogen, percent, 0.176

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

744 mm. Hg
First drop, 51° C. (121° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. L. 60° F.	C. I.	Refractive index N _D at 20° C.	Specific dispersion	S. U. vis., 100° F.	Cloud test, ° F.
1	128	1.1	1.1	0.666	81.0	-				
2	167	1.0	2.1	0.686	74.8	151	1.39175	123.8		
3	212	2.3	4.4	0.706	68.9	151	1.40752	122.5		
4	267	3.4	7.8	0.732	61.8	18	1.41704	123.9		
5	302	3.5	11.3	0.750	57.2	21	1.42682	123.8		
6	347	4.0	15.3	0.768	52.3	24	1.43719	127.7		
7	392	3.5	18.8	0.785	47.8	28	1.44814	128.0		
8	437	3.8	22.6	0.813	42.6	30	1.45908	128.0		
9	482	3.9	26.6	0.834	38.2	35	1.47043	135.1		
10	527	5.0	31.6	0.854	34.2	40				

800 mm. Hg
First drop, 51° C. (121° F.)

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr. 60/60° F.	A. P. L. 60° F.	C. I.	Refractive index N _D at 20° C.	Specific dispersion	S. U. vis., 100° F.	Cloud test, ° F.
11	392	2.5	34.1	0.872	30.8	44	1.48146	135.7	43	Below 5
12	437	4.7	38.8	0.894	28.6	46	1.48657	149.5	51	10
13	482	4.7	43.5	0.894	26.8	47	1.49168	159.1	71	15
14	527	5.2	48.7	0.905	24.2	51	1.50067	151.8	125	22
15	572	6.4	55.1	0.921	22.1	54	1.50672	-	320	30
Residuum		44.2	99.3	0.984	12.3					

Ramabottom carbon residue: Residuum, 4.4 percent; crude, 2.1 percent.
Equivalent Conradson carbon residue: Residuum, 6.0 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. gr.	A. P. L.	Viscosity
Total gasoline and naphtha	18.8	0.691	73.2	
Kerosene distillate	3.9	0.744	28.7	
Gas oil	13.4	0.855	42.6	
Nonviscous lubricating distillate	7.8	0.883-0.902	28.8-25.4	50-100
Medium lubricating distillate	3.6	0.902-0.912	25.4-23.7	100-200
Viscous lubricating distillate	7.6	0.912-0.928	23.7-21.0	Above 200
Residuum	44.2	0.984	12.3	
Distillation loss	1.7			

Item 5a

Bureau of Mines Bartlesville Laboratory Sample
57087
October 12, 1957

IDENTIFICATION

Kind field Kansas
Bartlesville sand Labette County
560-575 feet 348-128-6th

GENERAL CHARACTERISTICS

Specific gravity, ... 0.889 A. P. I. gravity, ... 25.9° Pour point, ° F., below 5
Sulfur, percent 0.57 Color, brownish black
Saybolt Universal viscosity at 100° F., 163 sec. (30.8 sp.) Nitrogen, percent, 0.174
130° F., 106 sec. (12.9 sp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brain 1—Distillation at atmospheric pressure, 731 mm. Hg
First drop, 35 ° C. (95 ° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. Gr., 60° F.	A. P. I., 60° F.	C. I.	Refractive index, No. at 20° C.	Specific dispersion	S. U. index, 100° F.	Cloud test, 100° F.
1	128	0.5	0.5	0.849	85.5	15	1.38215	120.5		
2	167	2.2	2.7	0.855	75.7	24				
3	215	3.9	6.6	0.865	63.7	21				
4	267	2.6	9.2	0.875	50.0	21				
5	308	3.6	12.8	0.885	36.2	21	1.41815	121.3		
6	347	3.4	16.2	0.892	21.6	23	1.42774	121.8		
7	388	3.3	19.5	0.898	6.2	26	1.43739	122.6		
8	427	3.9	23.4	0.904	42.3	31	1.44851	127.5		
9	468	4.0	27.4	0.917	37.6	36	1.45978	136.9		
10	537	5.1	32.5	0.927	33.6	41	1.47124	143.1		

Brain 2—Distillation continued at 40 mm. Hg

11	582	3.7	36.2	0.877	29.9	46	1.48344		46	Below 5
12	487	5.1	39.6	0.882	27.1	50	1.48858		57	Below 5
13	485	5.1	43.7	0.901	25.6	51	1.49521		84	15
14	587	5.3	49.0	0.914	23.3	54	1.50269		160	30
15	575	6.7	55.7	0.925	21.5	56	1.50768		400	40
Residue		42.4	98.1	0.955	12.2					

Ramifications carbon residues: Residue, 6.8 percent; crude, 3.2 percent.

Equivalent Conradson carbon residues: Residue, 10.1 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. Gr.	A. P. I.	Viscosity
Total gasoline and naphtha	4.9	0.897	74.5	
Kerosene distillate	17.8	0.877	57.9	
Gas oil	3.9	0.814	42.3	
Nonviscous lubricating distillate	12.6	0.856	33.8	
Medium lubricating distillate	8.4	0.882	28.9-25.2	50-100
Viscous lubricating distillate	4.7	0.916	25.2-23.0	100-200
Residue	8.3	0.916	23.0-20.5	Above 200
Distillation loss	42.4	0.885	42.2	
	1.9			

Item 6

Bureau of Mines Bartlesville Laboratory Sample
56104
September 11, 1956

IDENTIFICATION

Big Sandy field Kansas
Bartlesville Woodson County
1,230-1,250 feet 268-148-6th

GENERAL CHARACTERISTICS

Specific gravity, ... 0.921 A. P. I. gravity, ... 22.1° Pour point, ° F., below 5
Sulfur, percent 0.64 Color, brownish black
Saybolt Universal viscosity at 100° F., 123 sec. (36.7 sp.) Nitrogen, percent, 0.213
130° F., 215 sec. (39.3 sp.)

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

Brain 1—Distillation at atmospheric pressure, 738 mm. Hg
First drop, 30 ° C. (86 ° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. Gr., 60° F.	A. P. I., 60° F.	C. I.	Refractive index, No. at 20° C.	Specific dispersion	S. U. index, 100° F.	Cloud test, 100° F.
1	128	1.4	1.4	0.706	68.9					
2	167	1.4	2.8	0.740	59.7	22				
3	215	1.4	4.2	0.761	54.4	24				
4	267	1.4	5.6	0.780	49.9	26				
5	308	1.9	7.5	0.805	44.3	32	1.42391	127.8		
6	347	2.4	9.9	0.827	39.6	37	1.45573	133.0		
7	388	3.1	13.0	0.847	35.6	41	1.46502	135.6		
8	427	3.1	16.1	0.868	32.3	44	1.47457	143.3		
9	468	6.1	22.1							
10	537									

Brain 2—Distillation continued at 40 mm. Hg

11	582	2.0	24.1	0.880	29.3	48	1.48556	149.2	44	Below 5
12	487	6.9	31.0	0.882	27.1	49	1.48958	154.2	54	do.
13	485	5.0	36.0	0.901	25.6	51	1.49752	162.5	81	do.
14	587	5.9	41.9	0.915	23.1	54	1.50235	183.0	140	do.
15	575	6.7	48.6	0.922	22.0	58			340	do.
Residue		49.9	98.2							

Ramifications carbon residues: Residue, 4.7 percent; crude, 2.5 percent.

Equivalent Conradson carbon residues: Residue, 6.3 percent.

APPROXIMATE SUMMARY

Light gasoline	Percent	Sp. Gr.	A. P. I.	Viscosity
Total gasoline and naphtha	1.4	0.706	68.9	
Kerosene distillate	8.5	0.762	54.2	
Gas oil	17.1	0.817	42.3	
Nonviscous lubricating distillate	9.4	0.887	30.5	28.0-24.9
Medium lubricating distillate	5.6	0.915	24.9-22.8	50-100
Viscous lubricating distillate	7.7	0.917	22.8-21.3	100-200
Residue	49.9	0.922	22.0-21.3	Above 200
Distillation loss	1.8			

Item 6a

Bureau of Mines Bartlesville Laboratory Sample 57087
Sample 57087 September 27, 1937

IDENTIFICATION

Big Sandy field
Bartlesville sand
1,250 - 1,300 feet

Kansas
Woodson County
26 S.-14 E.-6th

GENERAL CHARACTERISTICS

Specific gravity, 0.916
Sulfur, percent, 0.56
Saybolt Universal viscosity at 100° F., 328 sec. (63.8 cp.)
130° F., 220 sec. (36.1 cp.)
A. P. I. gravity, 23.0°
Pour point, ° F., below 5
Color, brownish black
Nitrogen percent, 0.202

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1—Distillation at atmospheric pressure, 74.6 mm. Hg
First drop, 47° C. (117° F.)

Fraction No.	Cut temp., ° F.	Percent	Sum, percent	Sp. Gr., 60/60° F.	A. P. I., 60° F.	C. I.	Refractive Index, 20° C.	Specific dispersion	S. U. index, 100° F.	Cloud point, ° F.
1	122									
2	167	1.6	1.6	0.731	62.1	-				
3	218	1.4	3.0	.744	58.7	24				
4	257	1.5	4.5	.763	54.0	25				
5	302	1.7	6.2	.776	50.9	24				
6	347	2.4	8.6	.806	44.1	32	1.42244	128.7		
7	392	3.2	11.8	.829	39.2	38	1.45490	134.4		
8	437	4.5	16.3	.848	35.4	41	1.46486	137.3		
9	482	5.0	21.3	.864	32.3	44	1.47410	142.1		
10	527									

STAGE 2—Distillation continued at 40 mm. Hg

11	392	3.0	24.3	0.877	29.9	46	1.48013	-	44	14
12	437	6.1	30.4	.889	27.7	48	1.48898	-	52	30
13	482	5.6	36.0	.901	25.6	51	1.49551	-	73	62
14	527	5.6	41.6	.917	22.8	55	1.50216	-	130	54
15	572	7.2	48.8	.926	21.3	56	1.50759	-	290	62
Residue		48.6	97.4	.975	13.6					

Ramobottom carbon residue: Residue, 5.2 percent; crude, 2.7 percent.
Equivalent Conradson carbon residue: Residue, 6.9 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	A. P. I.	Viscosity
Light gasoline	1.6	0.731	62.1	
Total gasoline and naphtha	8.6	0.769	58.5	
Kerosine distillate	-	-	-	
Gas oil	17.7	.858	33.4	
Nonviscous lubricating distillate	9.6	.886-.909	28.2-24.2	50-100
Medium lubricating distillate	5.8	.909-.921	24.2-22.1	100-200
Viscous lubricating distillate	7.1	.921-.931	22.1-20.5	Above 200
Residue	48.6	.975	13.6	
Distillation loss	2.6			